

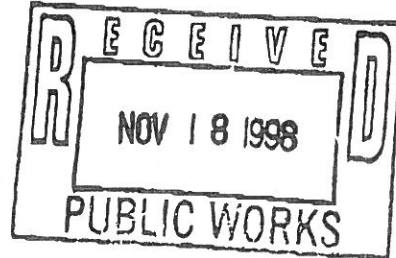


## ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

Governor Jane Dee Hull

Russell F. Rhoades, Director

November 13, 1998  
REF: PRU98-570



Ben Fisk  
City of Flagstaff  
211 West Aspen Ave.  
Flagstaff, AZ 86001

**RE: Paper Pulp Demonstration Project  
City of Flagstaff, Cinder Lake Landfill**

Dear Mr. Fisk:

On November 4, 1998, the Arizona Department of Environmental Quality's (ADEQ) Solid Waste Plan Review Unit (PRU) received and reviewed the City of Flagstaff's letter requesting a variance and preliminary report, *Paper Pulp as Alternative Daily Cover (ADC) Pilot Project Summary, November 17, 1997, thru September 30, 1998*. The preliminary report indicates that the paper pulp sludge is performing as a daily cover in accordance with Title 40 Code of Federal Regulations (CFR) 258.21. There also appears to be no violation of any health or environmental nuisance rules, nor a conflict with 40 CFR 258. The requested variance is to allow the City of Flagstaff to continue utilizing paper pulp sludge as an ADC beyond the one year pilot project period of one year that ends on November 14, 1998.

On May 7, 1998, ADEQ received the *Solid Waste Facility Plan, Cinder Lake Landfill, Flagstaff, Arizona*, Volume I through III, dated May 5, 1998. Section 7.1.6.2, Daily Cover, includes the operating conditions for the use of paper pulp waste which appear to be consistent with the pilot project conditions. Since the preliminary report indicates that there is no problem associated with the use of paper pulp sludge as an ADC and the submitted facility plan contains appropriate operating conditions, the City of Flagstaff may continue to use paper pulp sludge beyond the November 14, 1998, deadline, provided the following conditions are met:

- A summary report is submitted to ADEQ by December 14, 1998, in accordance with ADEQ's approval letter (PRU97-553). The report will be included in the technical review of the facility plan.
- The City of Flagstaff complies with the conditions of Section 7.1.6.2 of the *Solid Waste Facility Plan, Cinder Lake Landfill, Flagstaff, Arizona*, dated May 5, 1998.

Ben Fisk

November 13, 1998

PRU98-570

Page 2

This letter shall not be construed as a determination by ADEQ of compliance with any other applicable State or federal regulations.

If you have any questions concerning this letter, please contact me at (602) 207-4581, or toll free (in Arizona) at (800) 234-5677, extension 4581.

Sincerely,

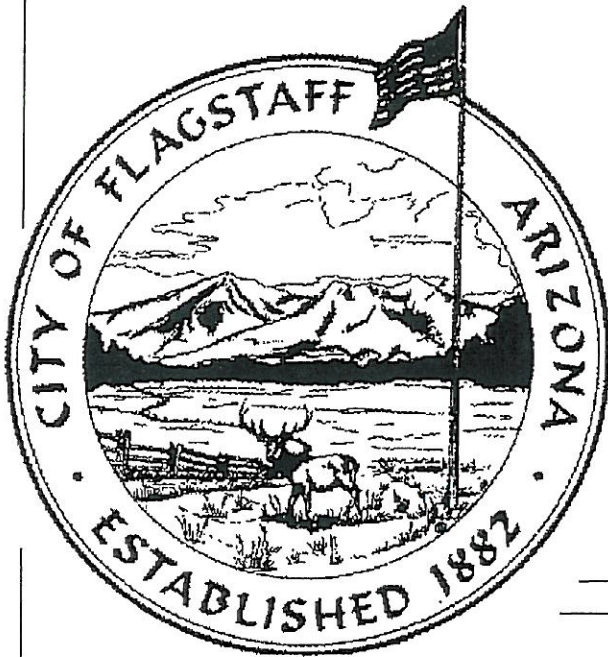


Gregory H. Brown, P.E.

Solid Waste Project Officer

Solid Waste Plan Review Unit

cc: Dave Phillips, Plan Review Unit  
Nicole Heffington, Plan Review Unit  
Steve Tighe, Plan Review Unit  
Facility File



**CINDER LAKE LANDFILL  
PAPER PULP WASTE  
FOR ALTERNATIVE DAILY COVER  
PILOT PROJECT SUMMARY REPORT**

**PROJECT NUMBER: 20-97719  
DECEMBER 1998**



**Prepared by**

**CITY OF FLAGSTAFF**

**Harley Grosvenor P.E., Environmental Manager  
Sarah Kelly, Environmental Scientist**

# Table of Contents

INTRODUCTION.....	1
BACKGROUND .....	2
PAPER PULP WASTE.....	2
CHARACTERISTICS .....	2
QUANTITY.....	3
LANDFILL OPERATIONS WITH PAPER PULP ADC .....	3
QUANTITY.....	3
USE AS ADC .....	3
THICKNESS.....	4
STOCKPILES .....	4
PAPER PULP ADC MIXES.....	4
FIRE HAZARDS ASSOCIATED WITH PAPER PULP ADC.....	5
LENGTH OF EXPOSURE OF PAPER PULP ADC.....	5
PAPER PULP EFFECTIVENESS AS ADC (AS PER 40 CFR 258.21).....	5
DAILY OBSERVATIONS .....	5
EFFECTS OF WEATHER.....	6
BENEFITS TO CLL OPERATION .....	6
CONCLUSIONS.....	6
RECOMMENDATIONS .....	7

Tables - Included at end of report

Table 1 - Laboratory Analysis Results

Figures - Included at end of report

Figure 1 - Location Map

Figure 2 - Graph, Tons of Paper Pulp Received Daily

Figure 3 - Histogram, Frequency of Number of Tons of Paper Pulp Received  
Daily

Figure 4 - Histogram, Number of Days Paper Pulp Exposed

Photo Logs - Included at end of report

Appendix A - Correspondence

Appendix B - Typical Completed Daily Data Sheets



*Harley J. Grosvenor*

## Introduction

On November 17, 1997, the City of Flagstaff (the City) started a pilot project to assess the effectiveness of paper pulp waste as an alternative daily cover (ADC) at the City's Cinder Lake Landfill (CLL). CLL, a municipal solid waste facility, is located approximately 12 miles northeast of Flagstaff, Arizona. CLL's location is shown on Figure 1. The paper pulp waste is produced by Wisconsin Tissue-Western of Flagstaff, AZ. URS Griener Woodward Clyde (formerly Woodward-Clyde Consultants) (UGWC) submitted for the City an ADC pilot program study proposal, pursuant to ARS 49-723.C, to the Arizona Department of Environmental Quality (ADEQ) dated August 13, 1997. The pilot project proposed testing the use of the paper pulp waste as an ADC. This submittal is included in Appendix A.

The City, UGWC, and Wisconsin Tissue-Western recognized that paper pulp waste similar to that generated by Wisconsin Tissue-Western is used as ADC at other solid waste facilities. The potential benefits of the re-use of the paper pulp waste as ADC at CLL instead of burying it as solid waste were also recognized. The constant, steady supply of paper pulp waste and its consistent quality made it an attractive candidate for use as ADC. Historically (from 1990 through 1997), the paper pulp waste comprised 10.2% to 25.9% of the total municipal solid waste stream at CLL. The material was produced by a single generator, currently owned by Wisconsin Tissue-Western, and was observed to have consistent physical characteristics from year to year.

The City proposed to use paper pulp waste as an ADC to conserve air space and to reduce landfill operational costs. The paper pulp waste had previously been disposed of by landfilling at CLL. The City proposed to recycle this material as an ADC instead of just burying it with other municipal solid waste. The use of this material as an ADC, in addition to conserving airspace at CLL, was expected to reduce the quantity of soil that would need to be borrowed from an on-site borrow area or imported to the site from off-site sources.

UGWC's August 13, 1997 submittal provided information on the proposed pilot project to fulfill ARS 49.723.C and ADEQ requirements. In a letter dated September 17, 1997 from ADEQ to the City, ADEQ stated that they may grant approval to CLL to perform a one-year pilot project of paper pulp waste as an ADC subject to several conditions which were listed in the letter. These conditions were addressed in the City's response to ADEQ dated October 28, 1997. This letter also served as a 10-day notice of the initiation of the pilot project, which the City anticipated starting on November 17, 1997. ADEQ replied to the City in a letter dated November 6, 1997, stating that ADEQ approved the pilot project commencing November 17, 1997 for a duration of one year. Copies of correspondence referenced here are included in Appendix A.

The City began the pilot project on November 17, 1997 under the conditions specified in correspondence with ADEQ. This report summarizes the data collected during the paper pulp waste as ADC pilot project. Observations on the effectiveness of this ADC are also discussed. The character and quantity of the paper pulp will be discussed first and a discussion of landfill operations with the paper pulp will be presented. Observations

demonstrating that the paper pulp waste ADC controls disease vectors, fires, odors, blowing litter, and scavenging will be presented.

## **Background**

CLL currently accepts municipal solid waste on a regional basis within a radius of approximately 75 miles. On average, CLL receives an estimated 390 tons of refuse per day. Daily disposal rate at CLL varies from approximately 2,000 tons per day (tpd) during the summer to 200 tpd during the winter. CLL operates seven days per week. Historic (beginning in 1985 when a scale was installed at CLL) disposal rates indicate that CLL receives between 112,000 and 171,000 total tons of municipal solid waste per year. Paper pulp sludge has historically comprised 10.2% to 25.9% of the total waste stream. General municipal waste has historically comprised 72.2% to 87.2% of the total waste stream. Other wastes (waste from lint-traps, grease traps, etc.) have historically comprised 1.0% to 5.5% of the total waste stream.

## **Paper Pulp Waste**

### ***Characteristics***

Laboratory analyses were conducted to assess the paper pulp waste for the characteristics of hazardous waste as described in Title 40 CFR 261, Subpart C. Two toxicity characteristic leaching procedure (TCLP) analyses were conducted on the paper pulp waste to assess toxicity for the contaminants listed in 40 CFR 261.24. Wisconsin Tissue, the producer of the paper pulp waste, supplied the City with the results of a hazardous characteristics' analysis prior to the start of the pilot project. This sample was collected at Wisconsin Tissue's facility on September 29, 1997. The City collected a sample from paper pulp at the CLL working face for complete hazardous characteristics' analysis, on July 30, 1998. Results for both sample analyses are listed in Table 1.

Density of the loose paper pulp as it was received at CLL was measured on February 26, 1998. The density was measured using a 0.5 cubic foot mold and beam balance obtained from the City Materials Testing Laboratory. The density of the loose paper pulp was measured at 41.1 pounds/cubic foot. An attempt was made to measure the density of compacted paper pulp. Paper pulp was compacted into the mold by hand. The weight of 0.5 cubic feet of paper pulp compacted in this way exceeded 36 pounds, the maximum amount of weights included with the beam balance. Density of the paper pulp waste placed by landfill equipment was not determined during this study.

No free moisture was observed on the paper pulp in the delivery trucks, in stockpiles at CLL, or on the working face at CLL. No remnant moisture was observed in the beds of delivery trucks after the paper pulp was unloaded at CLL. The paper pulp waste passed a paint filter test conducted on a sample collected by Wisconsin Tissue-Western on September 29, 1997. A paint filter test was conducted by City personnel on November 16, 1998 on paper pulp stockpiled at the working face at CLL. The paper pulp also passed this paint filter test.

### **Quantity**

The number of tons of paper pulp received per day was measured at the CLL scale and recorded on daily data sheets. Landfill operators estimated number of cubic yards per day received, used, and stockpiled, based on delivery truck size. Since these numbers are “eyeball” estimates by different individuals, they are considered approximate.

The total quantity of paper pulp waste received and used as ADC during the year-long pilot project was 30,400 tons. The average quantity received daily was 83 tons, with a standard deviation of 48 tons. The most commonly received daily quantities were between 60 and 100 tons. The maximum quantity received in one day was 264 tons. On 46 days no paper pulp was received. A graph depicting daily paper pulp tonnage received is presented in Figure 2. A histogram showing number of tons of paper pulp received per day is presented in Figure 3.

According to landfill operator estimates, up to 560 cubic yards (yds) of paper pulp were stockpiled in 150 yds stockpiles at CLL. Between June and September, 1998, some quantity of paper pulp was stockpiled overnight at the landfill almost every day. In this time period, paper pulp delivery was fairly regular and consistent. Between November 17, 1997 and early June 1998 paper pulp deliveries were less consistent and frequently no paper pulp would be stockpiled overnight.

## **Landfill Operations with Paper Pulp ADC**

### **Quantity**

Landfill operators estimated that approximately 200 yds were required to cover the working face with a 12-inch thickness of paper pulp. Using the density of uncompacted paper pulp, this converts to a minimum of approximately 110 tons required for daily cover. Since the most commonly received quantities ranged from 60 to 100 tons per day, it was frequently advantageous and necessary to stockpile paper pulp overnight when an excess of 110 tons was received in a day. Stockpiling of excess paper pulp when it was received allowed the slight shortfalls that occurred on “normal” days to be made up.

If there was not sufficient quantity of paper pulp available to completely cover the working face, wood-chips (green waste) or soil were mixed with the paper pulp to provide adequate daily cover. The use of green waste, soil, paper pulp and mixtures as ADC is discussed more thoroughly later in this section.

### **Use as ADC**

Paper pulp and paper pulp mixes were applied to the working face and at least two passes were made with the dozer (Caterpillar D8N) or compactor (Caterpillar 826G) to compact the paper pulp waste to thickness ranging from 8 to 12 inches. Photo logs 1 through 5 illustrate the typical use and appearance of the paper pulp ADC. Thickness will be discussed more thoroughly later in this section. Paper pulp was not used as daily cover when it was raining. The paper pulp would become too difficult to work with when it became excessively moist.

Matt, please explain  
"lift" w/rt landfill

Typical lift heights at CLL during the pilot project ranged from 12 to 20 ft slumping or creeping of paper pulp ADC or cells constructed on paper pulp observed. A minimum 12-inch layer of soil was used as intermediate cover for each horizontal lift. This continuous layer of soil would be expected to provide a fire break in the event of a fire.

### **Thickness**

Paper pulp ADC was applied at a thickness of 12-inches for the first three months of the pilot project. The 12-inch thickness met all of the requirements for daily cover, so operators began experimenting with thickness down to 8-inches in accordance with the ADC pilot study proposal. In-place thickness of the paper pulp ADC was difficult to measure. The compacted paper pulp and paper pulp mixes formed a very tough cover and it was difficult to penetrate the cover with a measuring device or to dig through. Thickness of the ADC was usually estimated by the operators as they laid the material down and was measured at the edge of the daily cover area. Thickness was often variable across the working face due to irregularities in the surface of the compacted garbage. Landfill operators often gauged the effectiveness of the cover by eye, making sure that all garbage was covered and that the ADC was adequately compacted. ADC thickness' from 8- to 12-inches were found to be effective.

### **Stockpiles**

As stated in the previous section, it was occasionally necessary to stockpile more than 150 cubic yards of paper pulp overnight to avoid landfilling the paper pulp. As stated in the City's October 28, 1997 letter to ADEQ, no paper pulp stockpile was to exceed 150 yds. Periodically, between June and September 1998, the large amount of paper pulp received daily created the necessity of stockpiling up to 560 yds overnight. CLL operators ensured that no individual stockpile exceeded 150 yds. All paper pulp stockpiles were monitored closely for signs of fire hazards, none were observed. These observations suggest that paper pulp stockpile size could be increased to 300 yds without creating a fire hazard. Photo log 5 shows a typical paper pulp stockpile.

A soil stockpile of at least 150 yds was maintained throughout the pilot project to be used for fire control. There were no instances during the pilot project in which the paper pulp appeared to represent a fire hazard. Photo log 9 shows a typical soil stockpile.

### **Paper Pulp ADC Mixes**

On occasion, the paper pulp waste was mixed with green waste or soil to be used as ADC. This was done when the quantity of paper pulp waste was insufficient to cover the working face. The mixture consisted of 40% green waste at maximum, but often with between 10%-30% green waste. Photo logs 7 through 10 illustrate the use and appearance of the paper pulp waste and green waste mix ADC. This mixture was very successful as an ADC. The paper pulp became easier for the equipment to work with when green waste was added to it.

Up to 20% soil was also occasionally mixed with the paper pulp to provide sufficient cover. Photo log 6 illustrates the appearance of the paper pulp waste and soil mix ADC. When these mixtures were used, they were applied to a thickness of 12-inches. Both of

these mixes met all of the requirements for daily cover, as will be discussed in the next section.

### ***Fire Hazards Associated with Paper Pulp ADC***

No fire hazards associated with paper pulp ADC were noted at any time during the pilot project.

### ***Length of Exposure of Paper Pulp ADC***

The ramping-up schedule defined in UGWC's August 13, 1997 submittal was followed during the pilot project. The ramping-up schedule was as follows:

<b>Time Frame</b>	<b>Maximum Days Paper Pulp Cover Exposed</b>
1st month	3 days
2nd month	7 days
3rd month	14 days
4-6 months	21 days
6+ months	30 days

The paper pulp functioned well for all time periods exposed. The paper pulp ADC was frequently covered the next day by the new cell. For this reason, on 69 occasions the ADC was left exposed for only one day. On 187 occasions, the paper pulp ADC was exposed for 7 days or less. On 152 occasions, the paper pulp ADC was left exposed for more than 7 days. The paper pulp ADC was left exposed for 14 or more days on 80 occasions. The paper pulp ADC was left exposed for 21 or more days on 23 occasions. Paper pulp ADC was left exposed for 30 days on only 2 occasions. The number of times that the paper pulp ADC was left exposed for any given number of days is shown in Figure 4.

## **Paper Pulp Effectiveness as ADC (as per 40 CFR 258.21)**

### ***Daily observations***

Daily observations by landfill personnel and weekly to bi-weekly observations by City Environmental Management personnel indicated that the paper pulp ADC and the mixtures of paper pulp and green waste or soil met all of the requirements for ADC as outlined in 40 CFR 258.21. Several typical daily paper pulp waste ADC data sheets are included in this report as Appendix B. All daily paper pulp waste ADC data sheets are available for review at the City's Environmental Management office. The use of paper pulp, and mixtures thereof, as ADC did not attract flies, birds, rodents, mosquitoes or other animals. No evidence of scavenging was observed during the pilot project. No increased odors or increased blowing litter were detected during the pilot project. No potential fire hazards were observed during the pilot project. No increase in dust was observed due to the paper pulp ADC. It was generally observed that areas of earthen cover produced more dust on windy days than did areas covered in paper pulp ADC. No excess infiltration was observed occurring on paper pulp ADC surfaces. The paper pulp ADC generally provides a more cohesive cover than the earthen materials

used at CLL. It is expected that the paper pulp ADC is less prone to infiltration than the earthen material used as daily cover because of its finer-grained, fibrous nature.

### ***Effects of Weather***

Changes in weather had only minimal effects on the paper pulp ADC cover. In the driest, hottest part of the summer (highs from 80°F to 95°F), a dried crust approximately 1- to 3-inches thick would form at the surface of the paper pulp ADC. This crust would form after approximately one to two weeks, depending on the ambient temperature, amount of rainfall, and wind conditions. The paper pulp continued to meet all of the requirements of daily cover when this dried crust was present. The paper pulp ADC was still very cohesive and still produced less visible dust than the earthen cover materials. Winter cold temperatures (lows from -15°F to 20°F) had the effect of freezing the paper pulp ADC into small (approximately 1-inch) clumps. These clumps would occur in a layer whose thickness would depend on whether the ADC was stockpiled or in place as cover and upon the temperature and amount of direct sunlight on the material. The paper pulp ADC met all of the requirements of daily cover in freezing temperatures. The only noticeable effect of freezing was that the paper pulp became more easily worked by the equipment.

### ***Benefits to CLL Operation***

The use of the paper pulp waste as ADC at CLL also represents a significant savings in airspace and therefore, lengthens the life of the landfill. The total number of tons of paper pulp received over the year of the pilot test was 30, 400 tons of loose material. Using the measured loose paper pulp density of 41.1 pounds/cubic foot this converts to a total of 54,789 cubic yards. Using an estimated compacted density of 70 pounds/cubic foot, this converts to a total of 32,200 cubic yards of airspace saved.

Earthen material was also conserved by the paper pulp waste as ADC project. A total of 54,789 cubic yards of loose paper pulp waste was used to provide an 8- to 12-inch thick daily cover. It is assumed that half that amount, approximately 27,000 cubic yards, of earthen material would have been required to provide 6-inches of daily cover. Therefore, approximately 27,000 cubic yards of earthen material has been conserved for later use as intermediate cover at CLL.

### **Conclusions**

Recycling of the paper pulp waste as an effective alternate daily cover material at CLL was demonstrated by the pilot test. The pilot project demonstrated that paper pulp waste meets the functional requirements of daily cover. This pilot project demonstrated that exposure to varying weather conditions had minor effects on the paper pulp ADC. These effects did not impair the paper pulp ADC in meeting the daily cover requirements of 40 CFR 258.21. Exposure of the paper pulp ADC to varying ambient conditions for up to 30 days demonstrated that paper pulp ADC surfaces were effective. Varying the thickness of the ADC from 8- to 12-inches did not change the effectiveness of the paper pulp ADC. Mixtures of paper pulp with green waste and/or soil were demonstrated to meet the ADC performance criteria.

## Recommendations

Continued recycling of paper pulp waste as ADC is recommended. The City proposes to continue using the paper pulp as ADC under the operating conditions described in the *Solid Waste Facility Plan, Cinder Lake Landfill, Flagstaff, Arizona*, Volume I through III, dated May 5, 1998, with section 7.1.6.2, Paper Pulp Waste, revised to read the following:

Paper pulp waste will be applied to the working face of the landfill with either scraper, dozer, or compactor and a minimum of two passes with either the dozer or compactor will be made. The compacted paper pulp will have a minimum thickness of 8 inches. The paper pulp waste will have a minimum moisture content of 65%. If the material becomes a dust nuisance, sufficient water will be applied immediately to eliminate the nuisance. Under rainy conditions, paper pulp will not be used as an ADC.

Paper pulp waste will be stockpiled near the working face for use as ADC. The paper pulp waste will not be exposed for more than 30 days. A soil stockpile will be maintained for use as intermediate and daily cover.

Paper pulp may be mixed with green waste and/or soil as necessary to provide ADC. Up to 600 cubic yards of paper pulp may be stockpiled at CLL to allow the most efficient use of the paper pulp as ADC. The size of individual paper pulp stockpiles will not exceed 300 cubic yards.

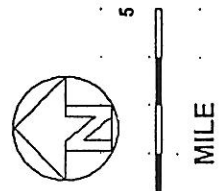
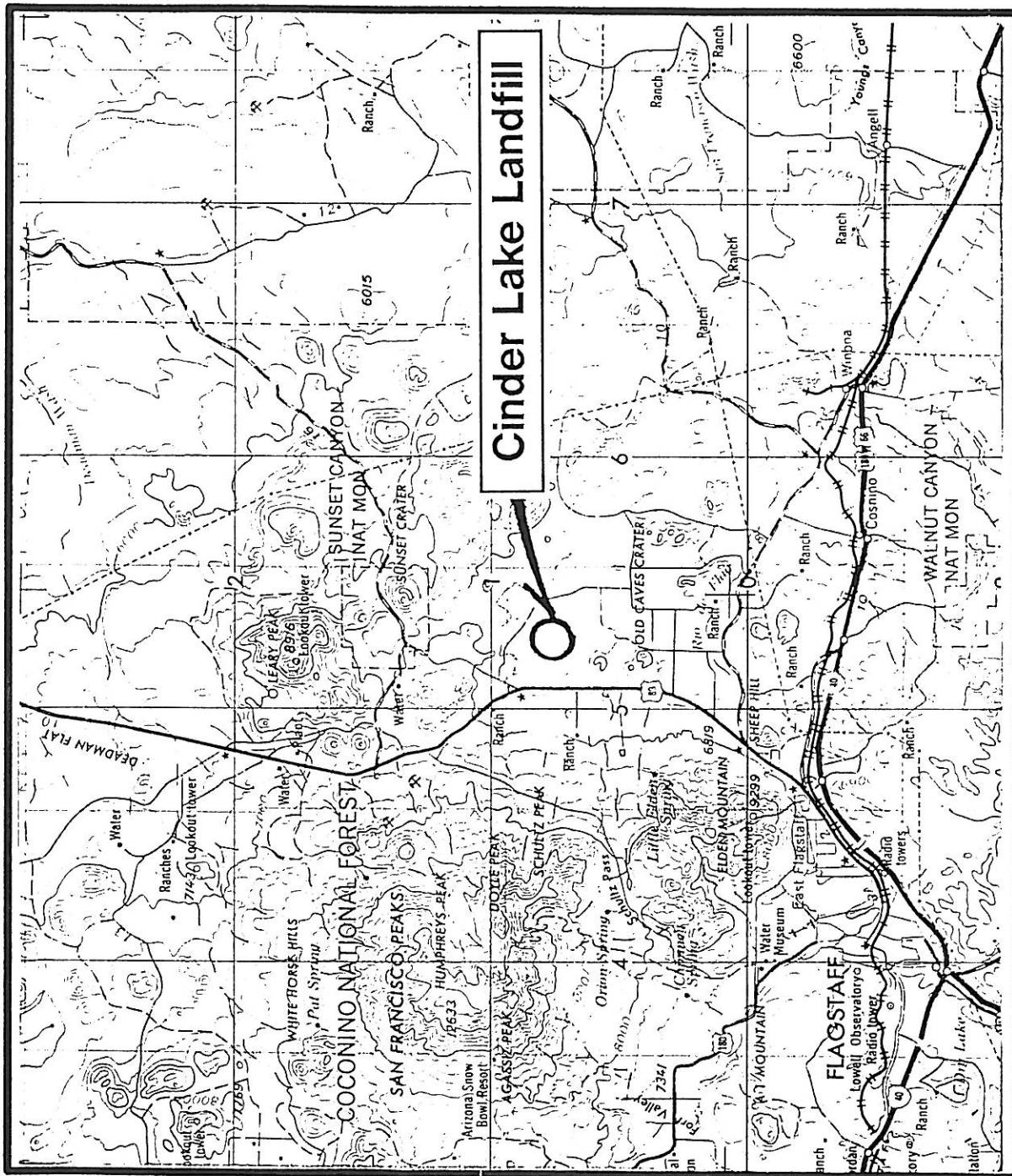
The City also proposes to discontinue the use of the pilot study daily data sheet. Periodic inspections by City Environmental Management personnel will continue.

# TABLES

**Table 1**  
**Laboratory Analysis Results**  
**Cinder Lake Landfill**  
**Paper Pulp ADC Pilot Project**

Parameter	Sept. 29, 1997 Sample	July 30, 1998 Sample	Maximum Concentration per 40 CFR 261.24
Arsenic, mg/L	<0.05	<0.5	5
Barium, mg/L	0.33	<10	100
Benzene, mg/L	<0.0005	<0.010	0.5
Cadmium, mg/L	<0.005	<0.050	1
Carbon Tetrachloride, mg/L	<0.0005	<0.025	0.5
Chlordane, mg/L	<0.0006	<0.003	0.03
Chlorobenzene, mg/L	<0.0005	<0.010	100
Chloroform, mg/L	0.0095	<0.010	6
Chromium, mg/L	<0.01	<0.10	5
Cresol, mg/L	<0.01	<20	200
2,4-D, mg/L	<0.020	<1.0	10
1,4-Dichlorobenzene, mg/L	<0.005	<0.75	7.5
1,2-Dichloroethane, mg/L	<0.0005	<0.010	0.5
1,1-Dichloroethylene, mg/L	<0.0005	<0.025	0.7
2,4-Dinitrotoluene, mg/L	<0.005	<0.013	0.13
Endrin, mg/L	<0.00002	<0.002	0.02
Heptachlor, mg/L	<0.00002	<0.0008	0.008
Heptachlor Epoxide, mg/L	<0.00003	<0.0008	0.008
Hexachlorobenzene, mg/L	<0.005	<0.013	0.13
Hexachlorobutadiene, mg/L	<0.005	<0.050	0.5
Hexachloroethane, mg/L	<0.030	<0.30	3
Lead, mg/L	<0.05	<0.50	5
Lindane, mg/L	<0.00002	<0.040	0.4
Mercury, mg/L	<0.004	<0.020	0.2
Methoxychlor, mg/L	<0.00003	<1.0	10
Methyl ethyl ketone, mg/L	<0.010	<0.050	200
Nitrobenzene, mg/L	<0.005	<0.20	2
Pentachlorophenol, mg/L	<0.005	<10	100
Pyridine, mg/L	<0.010	<0.50	5
Selenium, mg/L	0.11	<0.60	1
Silver, mg/L	<0.01	<0.50	5
Tetrachloroethylene, mg/L	0.00074	<0.010	0.7
Toxaphene, mg/L	<0.002	<0.050	0.5
Trichloroethylene, mg/L	<0.0005	<0.010	0.5
2,4,5-Trichlorophenol, mg/L	<0.005	<40	400
2,4,6-Trichlorophenol, mg/L	<0.005	<0.20	2
Silvex, mg/L	<0.004	<0.10	1
Vinyl Chloride, mg/L	<0.0005	<0.025	0.2
pH		7.2	
Reactive Cyanide, mg/Kg		<0.25	
Reactive Sulfide, mg/Kg		<1.0	
Flashpoint		>60° Celsius	

# FIGURES



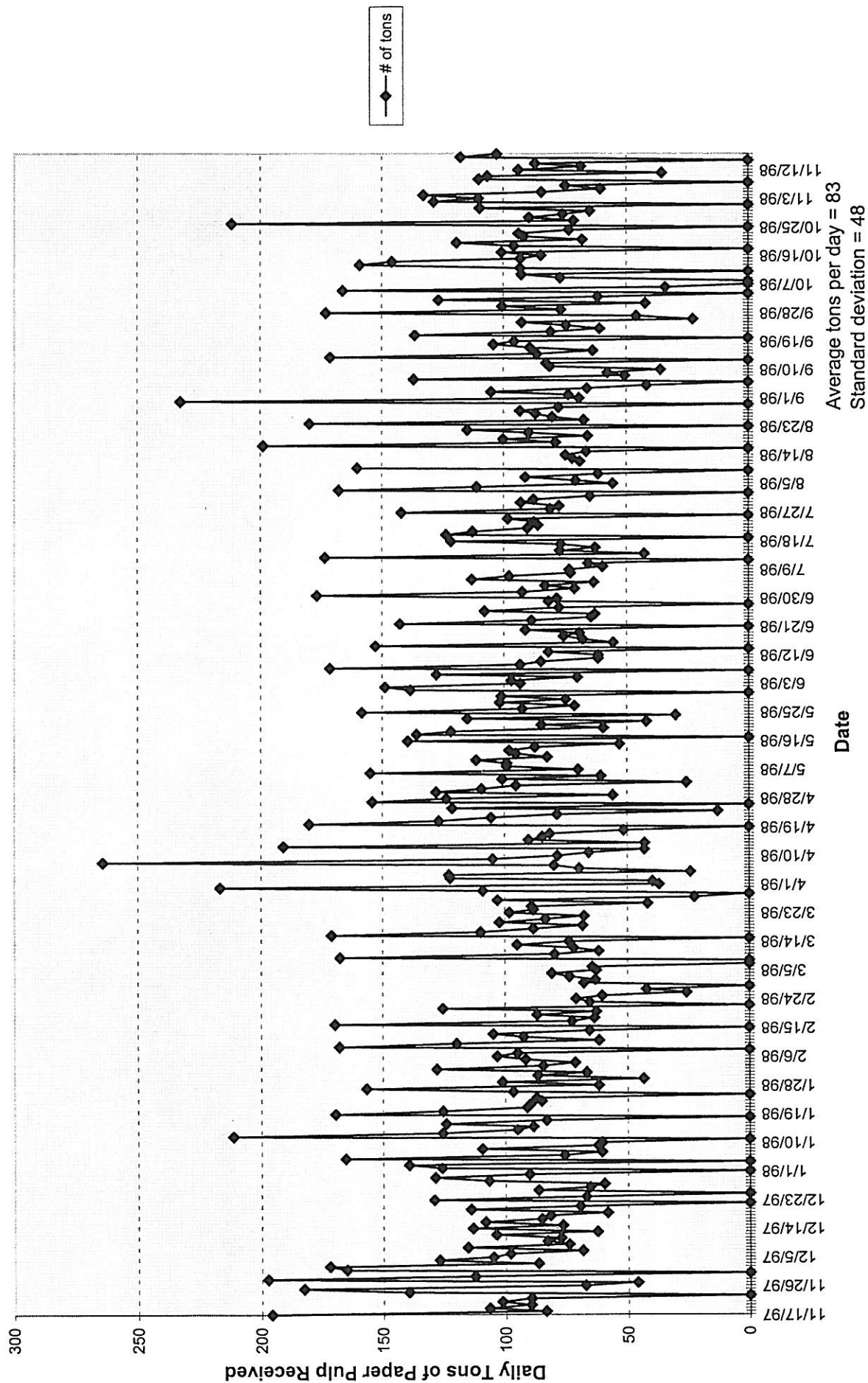
**Cinder Lake Landfill**

LOCATION MAP  
CINDER LAKE LANDFILL

FN: CINDER5	DRAWN BY: JD	CHECKED BY: JMA	PROJECT NO: 96A199	DATE: 3-30-98	FIGURE NO: 1
-------------	--------------	-----------------	--------------------	---------------	--------------

Figure 2

Cinder Lake Landfill, Tons of Paper Pulp Received Daily



# Figure 3

Cinder Lake Landfill, Frequency of Number of Tons of Paper Pulp Received per Day

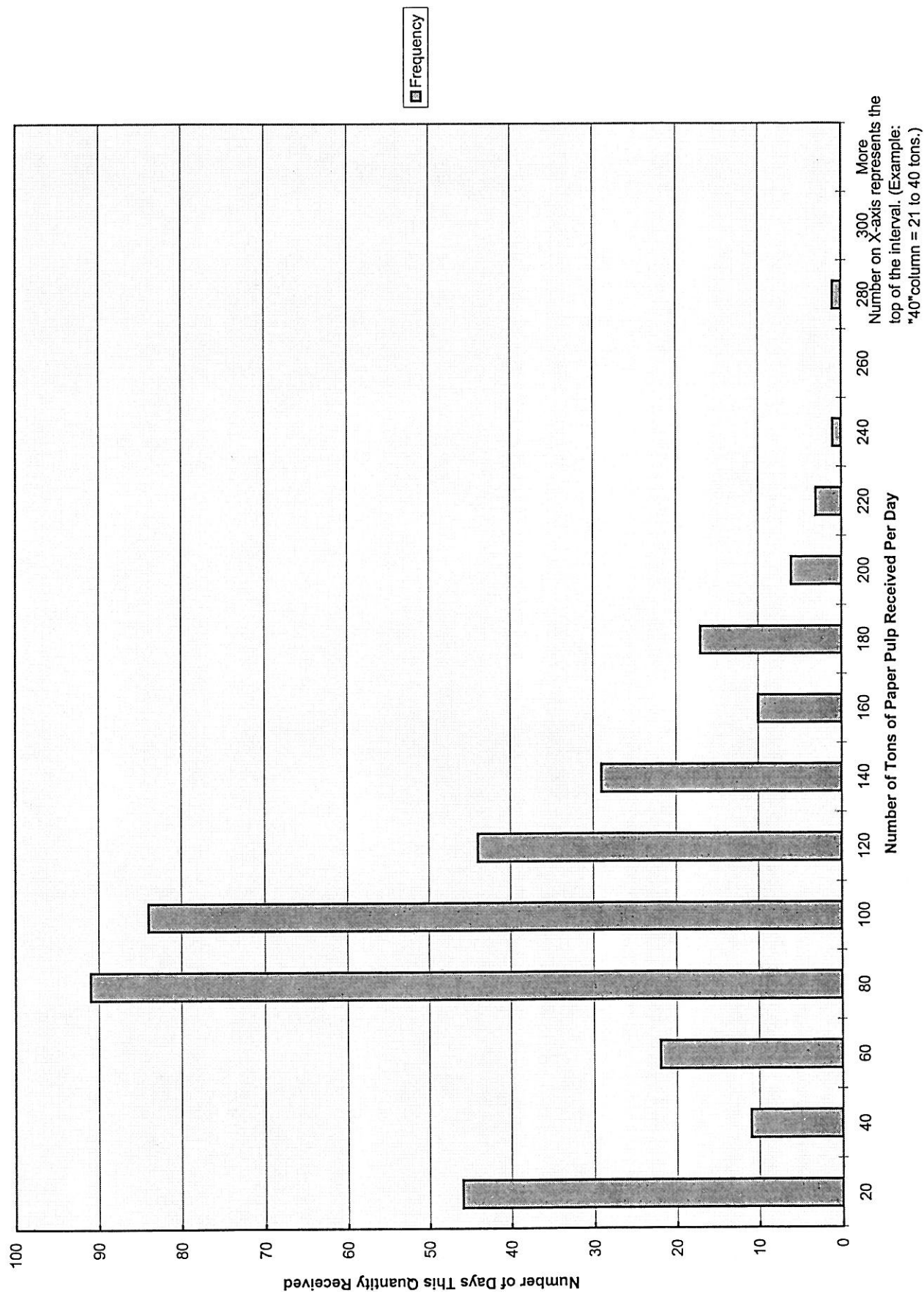
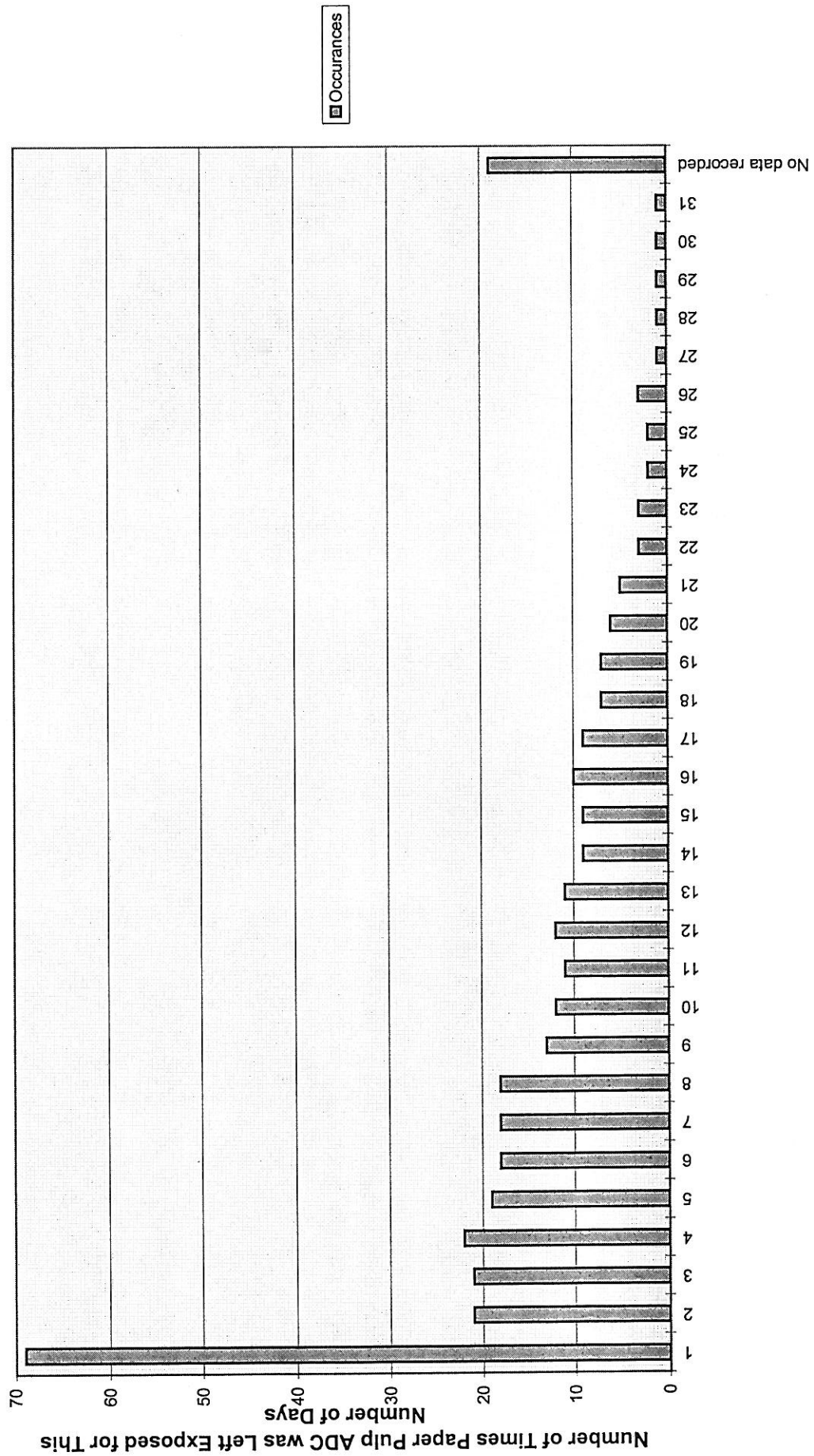


Figure 4

Cinder Lake Landfill, Number of Days Paper Pulp Exposed



Number of Days Paper Pulp Exposed

# PHOTO LOGS

**Cinder Lake Landfill  
Alternative Daily Cover Pilot Project  
September 18, 1998 Photographs**



**Forward view of working face and paper pulp ADC**



**Forward view of working face and ADC paper pulp.**

**Cinder Lake Landfill  
Alternative Daily Cover Pilot Project  
September 18, 1998 Photographs**



**Close-up of paper pulp ADC**



**View of dirt cover east of current working face.**

Cinder Lake Landfill  
Alternative Daily Cover Pilot Project  
July 23, 1998



Paper pulp ADC, cinder, and dirt covered slope.



Paper pulp ADC, dirt, and working face.

Cinder Lake Landfill  
Alternative Daily Cover Pilot Project  
April 28, 1998 Photographs



Side view of paper pulp ADC covered area



Closeup of paper pulp ADC

Cinder Lake Landfill  
Alternative Daily Cover Pilot Project  
April 28, 1998 Photographs



Paper pulp stockpiles



Paper pulp ADC covered area

**Cinder Lake Landfill  
Alternative Daily Cover Pilot Project  
January 29, 1998 Photographs**



**Paper pulp + 10%-20% dirt**



**Closeup of paper pulp + 10%-20% dirt**

**Cinder Lake Landfill  
Alternative Daily Cover Pilot Project  
January 8, 1998 Photographs**



**Working face, paper pulp, green waste, and dirt piled at top**



**Close up of piles of paper pulp, green waste, and dirt at top of working face.**

**Cinder Lake Landfill  
Alternative Daily Cover Pilot Project  
January 8, 1998 Photographs**



**Close-up of paper pulp + green waste, cover from a previous day**



**Working face and adjacent slopes**

**Cinder Lake Landfill  
Alternative Daily Cover Pilot Project  
December 11, 1997 Photographs**



**Close-up of paper pulp and green waste mixed**



**Soil Stockpile for fire suppression**

Cinder Lake Landfill  
Alternative Daily Cover Pilot Project  
January 8, 1998 Photographs  
JRK



Paper pulp+green waste cover with dirt covered side slope



Dirt covered side slopes at the most beautiful landfill in Northern Arizona.

# APPENDIX A

August 13, 1997

Mr. Larry K. Lampert, P.E.  
Environmental Engineer  
Arizona Department of Environmental Quality  
3003 North Central Avenue  
Phoenix, AZ 85012-2905

Subject: Paper Pulp Waste for Alternative Daily Cover  
Cinder Lake Landfill, Flagstaff, Arizona  
Woodward-Clyde Project No. 96A199-1101  
ADEQ Reference No. PRU97-200

Dear Mr. Lampert:

On behalf of the City of Flagstaff (City), and in response to your letter dated June 13, 1997, Woodward-Clyde International-Americas (Woodward-Clyde) is pleased to submit this request to conduct a pilot project for the use of paper pulp waste as an alternative daily cover (ADC), as a new method for solid waste management at the Cinder Lake Landfill (CLL) in Flagstaff, Arizona. This request is pursuant to provisions in Arizona Revised Statute (ARS) §49-723.C.

The following information is provided as requested in your June 13, 1997 letter. The specific request is repeated in *italic* to facilitate review.

1. *The City should propose the use of paper pulp waste for a pilot project and provide justification to ADEQ why it is necessary to use the pulp as ADC at the Cinder Lake Landfill.*

The City proposes to use paper pulp waste as an ADC to conserve air space and to reduce landfill operational costs. The paper pulp waste has in the past and is currently being disposed by landfilling at CLL. The City proposes to use this material as an ADC instead of just burying it with other municipal solid waste (MSW). The use of this material as an ADC will, in addition to conserving air space at the landfill, reduce the quantity of soil that would need to be borrowed from an on-site borrow area or imported to the site from off-site sources.

Mr. Larry K. Lampert, P.E.  
Arizona Department of Environmental Quality  
August 13, 1997  
Page 2

2. *The City should describe what data will be collected and reported as part of the pilot project.*

Data will be collected daily on the data collection worksheet in Appendix A. This information will be compiled and reported monthly to ADEQ. A summary report will be provided at the end of the pilot project. Additionally, laboratory testing of additional samples (see Response Number 3) will also be provided.

3. *The chemical composition of typical pulp shall be provided (several samples from several different years would be beneficial).*

The results of chemical analysis conducted in 1993, 1994, and 1995 can be found in Appendix B. Additionally, during the pilot project, Wisconsin Tissue will conduct chemical analysis on a semi-annual basis.

4. *City of Flagstaff must submit a proposed schedule for demonstrating the effectiveness of the pulp as an ADC. ARS § 49-723.C allows ADEQ to issue an exemption for up to one year for pilot projects at solid waste facilities; however, ADEQ thinks that determining effectiveness of this ADC will take less time than one year.*

The City requests a one-year schedule for completing the pilot project. Assuming that the project begins in August, the pilot project will run through hot and dry summer weather, a Monsoon season (heavy rain), a winter season (snow and freezing weather) and a spring rainy season. It is anticipated that the report of the pilot project will be prepared in May/June 1998 for submittal and review by ADEQ.

5. *At a minimum, the following information is required to make an ADC demonstration:*

- *Description of the method of application of the pulp and the equipment used to spread and compact the pulp.*

The paper pulp waste will be stockpiled near the working face as it is delivered to the site. A maximum stockpile size of 150 cubic yards is anticipated. The paper pulp waste will be applied to the working face with existing landfill equipment including the scraper, the dozer (Caterpillar D8N) or the compactor (Caterpillar 826C). Once applied, the ADC will be compacted by at least two passes with

Mr. Larry K. Lampert, P.E.  
Arizona Department of Environmental Quality  
August 13, 1997  
Page 3

either the 826C or the D8N to a thickness of at least 12 inches. The thickness of the paper pulp may be reduced based on verification that the reduced thickness will meet the requirements for daily cover. Since the paper pulp waste is currently being disposed at CLL, landfill equipment operators have experience with moving the paper pulp waste. The paper pulp waste behaves as would a clayey soil. Landfill personnel are very confident that the paper pulp waste can be applied as an ADC with the existing equipment.

- *The minimum moisture content that will be maintained in any exposed pulp.*

The as-received moisture content of the paper pulp waste received was 211 percent (of dry weight). Wisconsin Tissue will conduct at least one solids percent analysis per shift to assure that the paper pulp waste moisture content is consistent and that it does not fail the Paint Filter Liquids Test.

Samples of the pulp were compacted in pans to approximately 6-inch and allowed to air dry outside at Woodward-Clyde's San Diego soils lab for 5 days during sunny (80° - 90° F) conditions. After five days, the surface of the sample was hard and crusty to a depth of about 1 inch. The soil moisture content in this top 1-inch was measured at 123%. Brushing the surface with moderate force by hand did not loosen the surface or cause apparent dust. Discussions with other operators utilizing the paper pulp waste as ADC indicates that it does not dry enough to become a dust nuisance or fire hazard even when exposed for up to 1 month. It is anticipated that similar to clayey soils, the paper pulp will only become dusty when the moisture content drops to at or below optimum soil content (65% of dry weight for this material). If the material's moisture drops such that it becomes a dust nuisance, it will be wetted with the water truck. Therefore it is expected that the minimum moisture content that will be maintained in exposed pulp will be 65%.

- *The maximum number of consecutive days that the pulp will be used as ADC.*

The maximum number of days that the paper pulp will be used as ADC is expected to be 21 days. Based on experience from other landfills that use paper pulp waste as ADC, we believe that the paper pulp waste could be used for a much longer period. However, the Wisconsin Tissue facility periodically shuts

Mr. Larry K. Lampert, P.E.  
Arizona Department of Environmental Quality  
August 13, 1997  
Page 4

down for scheduled maintenance and the paper pulp waste supply at the landfill will run out during these periods.

As indicated in Section 4.2.2 of our previous report (dated May 30, 1997), we recommend that the paper pulp cover should not remain exposed for more than 30 days. This recommendation is based on experience at other landfill sites in the US that are using paper pulp waste as daily cover. If desired by ADEQ the City will agree to the following ramping-up schedule:

Time Frame	Maximum Days Paper Pulp Cover Exposed
1st month	3 days
2nd month	7 days
3rd month	14 days
4-6 months	21 days
6+ months	30 days

If at any point during the ramping-up schedule it becomes apparent that the paper pulp cover is exposed for too long a period of time (e.g. excessive dust, shrinkage exposing waste, etc.), the ramping-up schedule will be discontinued.

- *The physical properties of the pulp at varying moisture contents.*

The appearance and texture of the paper pulp waste was similar to soft clay granules for the range of moisture contents that were tested (45 to 200 percent of dry weight). Figure 1 of our report provides the dry density versus moisture content for a standard compactive effort (per ASTM D 698). Other investigations have found that the hydraulic conductivity generally decreases with increasing moisture content (Appendix C).

A direct relationships between moisture content and strength have not been fully investigated. Nevertheless, Woodward-Clyde conducted a first order attempt to develop an empirical correlation between moisture content and strength for compacted paper pulp has been attempted based on limited available information (Moo-Young, H.K. and Zimmie, T.F., "Geotechnical Properties of Paper Mill

Mr. Larry K. Lampert, P.E.  
Arizona Department of Environmental Quality  
August 13, 1997  
Page 5

Sludges for Use in Landfill Covers," ASCE Journal of Geotechnical Engineering, September, 1996).

The results of available upper and lower bound frictional strength as a function of moisture content are presented in Figure 1. Linear regression analyses for the upper and lower bound ranges are also presented thereon. The results of the single strength test performed by Woodward-Clyde (1997) indicated a frictional strength of 40 degrees and cohesion of 620 psf at about 10 percent shear strain deformation. This result is also presented on Figure 1.

The trendline on Figure 1 indicates that the frictional strength of compacted paper pulp increases with a reduction in moisture content. A proportional decrease in material volume associated with material shrinkage is expected to occur during the desiccation process since the paper pulp as received may be near saturation and considered somewhat plastic. However, the reader should be cautioned that data presented in Figure 1 may not be suitable for use in certain geotechnical analyses without further evaluation.

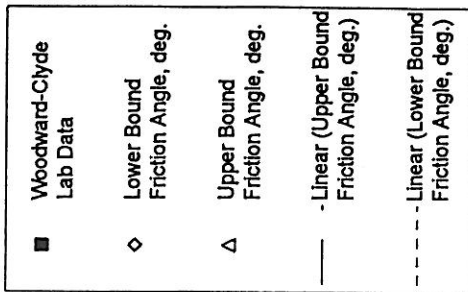
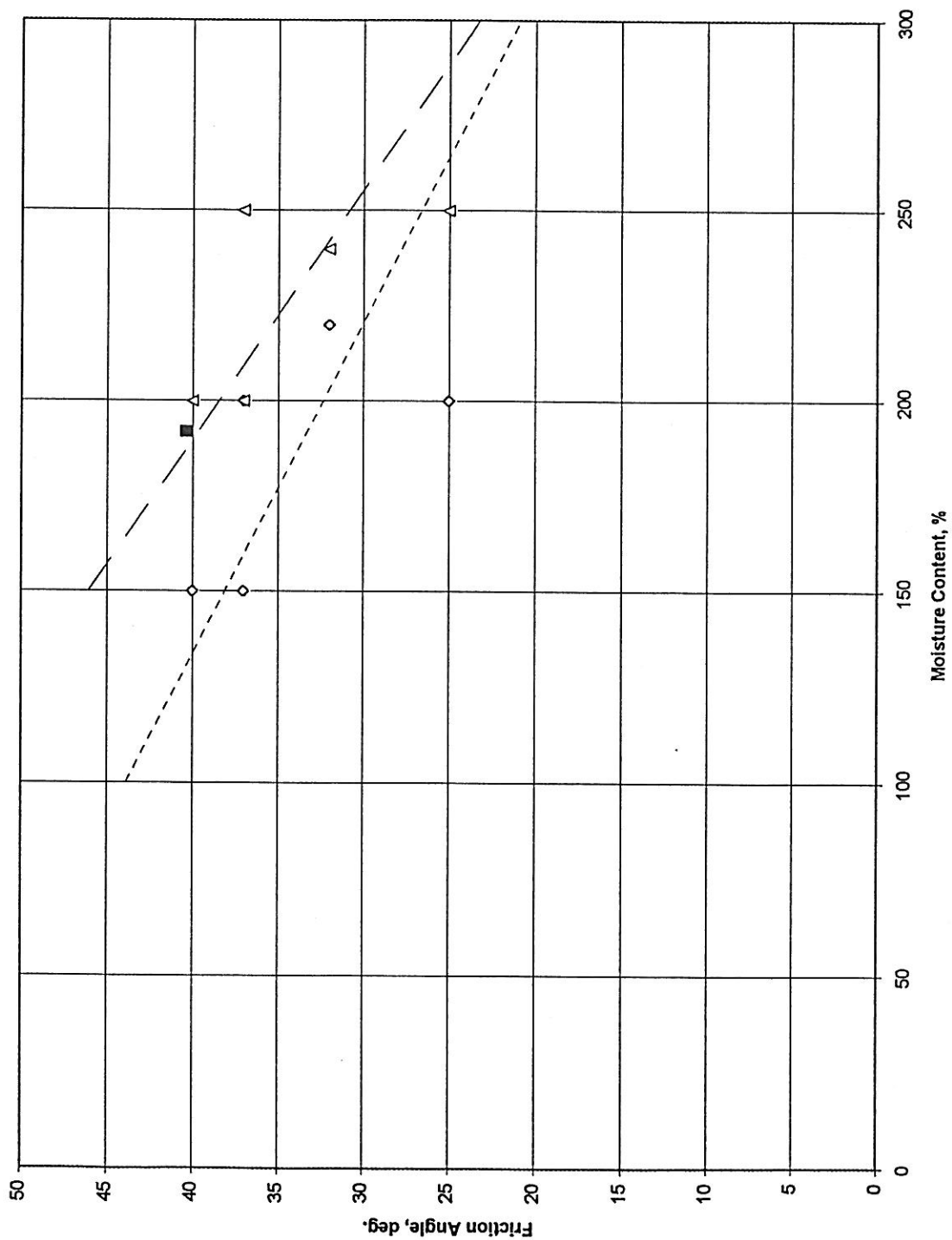
- *A description of any weather limitations (ie. temperatures, precipitation, wind speed, etc.) or other conditions that would require suspension of use of pulp.*

Paper pulp waste will not be used as ADC during raining conditions as this material will become very slippery and difficult to manage during wet weather conditions.

- *A demonstration that under both static and seismic loading the material will be stable. Specifically, demonstrate that the design parameters account for any long term creep of the predominantly clay material.*

The results of a strength test on the paper pulp waste is presented in Figure 2 of our report. A friction angle of 40 degrees with a cohesion of 60 psf was obtained from this test. This strength is similar to what other investigators have found. The relatively high strength (equivalent to a dense silty sand) is believed to be due to the fibrous nature of the paper pulp waste. These strength values are higher than what is typically used for MSW; therefore inclusion of the paper pulp waste as an ADC should not be detrimental to the static or dynamic stability of the

Paper Pulp Moisture Content vs. Strength



Mr. Larry K. Lampert, P.E.  
Arizona Department of Environmental Quality  
August 13, 1997  
Page 7

landfill. Furthermore, the stress-strain characteristics from the tests do not indicate lower residual strengths at higher strains that may occur if the material were to exhibit creep characteristics.

- *Specify the maximum height of the horizontal lift.*

A typical lift height at CLL is 12 feet. On occasion, a portion of a lift may be constructed to a height of 18 to 20 feet in order to reach the appropriate elevation for proper surface drainage.

- *Each horizontal lift shall be separated by a continuous layer of inert material that will provide a fire break; and*

A 12-inch layer of soil will be used as intermediate cover on the top of each horizontal lift.

- *Demonstration that the pulp will control fires. Acceptable fire control alternatives can include: maintenance of a soil stockpile to smother a fire; availability of an on-site fire suppression such as a water truck; periodic use of a prescribed six inches of soil for daily cover as a fire break; and/or any other alternative means to control fires.*

A soil stockpile will be maintained for use as intermediate cover. This stockpile will be available for fire suppression if needed. Additionally, the 3,200 gallon water truck used for dust control will also be available for fire suppression.

Finally, we anticipate that the land transfer with the US Forest Service (USFS) for the landfill expansion will be completed within the next 60 days. Assuming no additional delays by the USFS, the revised expansion design should be completed by year end and the ADEQ approval process reinitiated.

The responses provided in this letter combined with the information presented in our May 30, 1997 report is intended to provide information necessary for ADEQ to allow the initiation of

Mr. Larry K. Lampert, P.E.  
Arizona Department of Environmental Quality  
August 13, 1997  
Page 8

the requested ADC pilot project. If you have questions or require additional information, please call me at 619-683-6112.

Very truly yours,

WOODWARD-CLYDE INTERNATIONAL-AMERICAS

A handwritten signature in black ink, appearing to read 'D. Marx', with a stylized flourish at the end.

David E. Marx  
Project Manager

DEM:rad/msw

cc: Mr. Ben Fisk, City of Flagstaff  
Mr. Harley Grosvenor, City of Flagstaff

## APPENDIX A

# CINDER LAKE LANDFILL PAPER PULP WASTE ADC DATA SHEET

NAME: \_\_\_\_\_ DATE: \_\_\_\_\_

## PREDOMINANT WEATHER (check all that apply)

☐ cloudy   ☐ rain   ☐ sunny   ☐ windy   ☐ snow

Temperature	
____ high	____ low

## CHECK THE APPROPRIATE BOX

- |  | YES<br>(DETAIL<br>BELOW) | NO                       |
|--|--------------------------|--------------------------|
| 1. Pilot project has attracted                           |                          |                          |
| Flies  | <input type="checkbox"/> | <input type="checkbox"/> |
| Birds  | <input type="checkbox"/> | <input type="checkbox"/> |
| Rodents  | <input type="checkbox"/> | <input type="checkbox"/> |
| Mosquitos  | <input type="checkbox"/> | <input type="checkbox"/> |
| Other animals  | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Evidence of scavenging observed                       | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Increased odors detected from pilot project           | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Increased dust observed from pilot project            | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Increased blowing litter observed from pilot project  | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Potential fire hazard conditions observed             | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Operation problems related to the use of ADC          | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Paper pulp received appeared normal                   | <input type="checkbox"/> | <input type="checkbox"/> |
| 9. Number of paper pulp waste trucks deliveries received | _____                    |                          |
| 10. Quantity of paper pulp waste used as ADC             | _____                    |                          |
| 11. Number of days paper pulp waste used as ADC          | _____                    |                          |
| Other issues, problems and observations _____            |                          |                          |
| _____  |                          |                          |
| _____  |                          |                          |
| _____  |                          |                          |

## APPENDIX B



3700 Lakeville Highway, Petaluma, CA 94954  
Telephone: (707) 763-8245  
FAX (707) 763-4068

Andrew Stahl  
Dames & Moore-Phoenix  
7500 N. Dreamy Draw Dr., Suite 145  
Phoenix, AZ 85020

March 13, 1995  
Revised Report

Customer Project: 27541-005-155 Orchids Paper Phase II  
Laboratory Job: L9502231

On February 23, 1995 we received 3 sample(s) for analysis. Results for TRPH 418.1AZ are reported on a dry weight basis as noted in report. Detection limits have not been adjusted for percent moisture for this parameter. Samples were analyzed by the following methods:

418.1AZ (BLS 181)

Volatile Organic Compounds + TICs (EPA 8240)

Semi-volatile Organic Compounds + TICs (EPA 8270)

Total Cyanide (EPA 335.3 / 9010A)

Chromium by ICP (EPA 6010)

Copper by ICP (EPA 6010)

Mercury (EPA 7471)

Nickel (EPA 6010)

Lead (EPA 6010)

Zinc by ICP (EPA 6010)

Hold Samples

*Don Breaux*  
Project Manager

*Robert Peak*  
Laboratory Director  
Robert Peak

O&M Laboratories

ANALYTICAL DATA REPORT

Prepared for: Dames & Moore-Phoenix  
Project Id: 27341-003-155 Orchids Paper Phase II  
Sample Id: A  
Lab Id: L9502231-1

Collected: 22-FEB-95  
Received: 23-FEB-95  
Reported: 13-MAR-95

Arizona 418.1A2

Results Reported on a Dry Weight Basis

TPH	6300	200	mg/Kg	01-MAR-95	01-MAR-95
Total Cyanide					
Total Cyanide	ND <	2.0	mg/Kg	24-FEB-95	27-FEB-95
Cold Vapor AA					
Mercury - EPA 7471	0.010	0.010	mg/Kg	27-FEB-95	27-FEB-95
METALS - TJA EPA 6010					
Chromium-6010	26.	0.23	mg/Kg	01-MAR-95	02-MAR-95
Copper-6010	16.	0.23	mg/Kg	01-MAR-95	02-MAR-95
Lead-6010	3.1	0.50	mg/Kg	01-MAR-95	02-MAR-95
Nickel-6010	22.	0.39	mg/Kg	01-MAR-95	02-MAR-95
Zinc-6010	66.	0.50	mg/Kg	01-MAR-95	02-MAR-95
Volatile Organic Compounds-GC/MS					
Benzene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Bromodichloromethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Bromoform	ND <	10.	ug/Kg	01-MAR-95	01-MAR-95
Bromomethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Carbon tetrachloride	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Chlorobenzene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Chloroethane	ND <	10.	ug/Kg	01-MAR-95	01-MAR-95
Chloroform	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Chloromethane	ND <	10.	ug/Kg	01-MAR-95	01-MAR-95
Dibromochloromethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
1,1-Dichloroethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
1,1-Dichloroethene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
1,2-Dichlorobenzene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
1,3-Dichloroethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
1,3-Dichlorobenzene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
1,4-Dichlorobenzene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Cis-1,2-Dichloroethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Trans-1,2-Dichloroethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
1,2-Dichloropropene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Cis-1,3-Dichloropropene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Trans-1,3-Dichloropropene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Ethyl Benzene	41.	5.0	ug/Kg	01-MAR-95	01-MAR-95
Methylene Chloride	ND <	10.	ug/Kg	01-MAR-95	01-MAR-95
1,1,2,2-Tetrachloroethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Tetrachloroethene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Toluene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
1,1,1-Trichloroethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
1,1,2-Trichloroethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Trichloroethene	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Trichlorofluoromethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Trichlorotrifluoroethane	ND <	5.0	ug/Kg	01-MAR-95	01-MAR-95
Vinyl Chloride	ND <	10.	ug/Kg	01-MAR-95	01-MAR-95
Xylenes	160	5.0	ug/Kg	01-MAR-95	01-MAR-95
Acetone	37000	13000	ug/Kg	03-MAR-95	03-MAR-95
2-Butanone	21000	13000	ug/Kg	03-MAR-95	03-MAR-95

## B&amp;M Laboratories

## ANALYTICAL DATA REPORT

Prepared for: Samco & Moore-Phoenix  
 Project Id: 27841-003-158 Orchids Paper Phase II  
 Sample Id: A  
 Lab Id: L9502231-1

Collected: 22-FEB-95  
 Received: 23-FEB-95  
 Reported: 13-MAR-95

Compound	Conc.	Unit	Date	Date
Carbon Disulfide	33.	ug/Kg	01-MAR-95	01-MAR-95
2-Hexanone	55.	ug/Kg	01-MAR-95	01-MAR-95
4-Methyl-2-Pentanone	NO <	ug/Kg	01-MAR-95	01-MAR-95
Styrene	NO <	ug/Kg	01-MAR-95	01-MAR-95
Vinyl Acetate	NO <	ug/Kg	01-MAR-95	01-MAR-95
Surrogate:				
1,2-Dichloroethane-d4	93.9	%	01-MAR-95	01-MAR-95
Toluene-d8	124.	%	01-MAR-95	01-MAR-95
Bromofluorobenzene	82.5	%	01-MAR-95	01-MAR-95

## Comments:

Surrogate recoveries were out of control limits due to matrix effects. The analysis was repeated with similar results.

## GC/MS Semi-quantitative

Compound	Conc.	Unit	Date	Date
ALKANES	621.0	ug/Kg	01-MAR-95	01-MAR-95
UNDECANE	770.0	ug/Kg	01-MAR-95	01-MAR-95
Decahydro-2-Methyl-Naphthalene	661.0	ug/Kg	01-MAR-95	01-MAR-95
Pentylcyclohexane	215.0	ug/Kg	01-MAR-95	01-MAR-95
3-Methyl-Undecane	188.0	ug/Kg	01-MAR-95	01-MAR-95
Dodecane	990.0	ug/Kg	01-MAR-95	01-MAR-95
Spiro[5.5]Undecane	191.0	ug/Kg	01-MAR-95	01-MAR-95
6-Methyl-Tridecane	276.0	ug/Kg	01-MAR-95	01-MAR-95

## D&amp;M Laboratories

## ANALYTICAL DATA REPORT

Prepared for: Dames & Moore-Phoenix  
 Project Id: 27341-005-153 Archida Paper Phase II  
 Sample Id: A  
 Lab Id: L9302231-1

Collected: 22-FEB-95  
 Received: 23-FEB-95  
 Reported: 13-MAR-95

Benzoic Acid	ND <	1.0	mg/Kg	24-FEB-95	28-FEB-95
Benzyl alcohol	ND <	0.20	mg/Kg	24-FEB-95	28-FEB-95
4-Chloroaniline	ND <	0.20	mg/Kg	24-FEB-95	28-FEB-95
Dibenzofuran	ND <	0.20	mg/Kg	24-FEB-95	28-FEB-95
2-Methyl-naphthalene	ND <	0.20	mg/Kg	24-FEB-95	28-FEB-95
2-Methyl-Phenol	ND <	1.0	mg/Kg	24-FEB-95	28-FEB-95
4-Methyl-Phenol	ND <	1.0	mg/Kg	24-FEB-95	28-FEB-95
2-Nitroaniline	ND <	0.20	mg/Kg	24-FEB-95	28-FEB-95
3-Nitroaniline	ND <	0.20	mg/Kg	24-FEB-95	28-FEB-95
4-Nitroaniline	ND <	1.0	mg/Kg	24-FEB-95	28-FEB-95
2,4,5-Trichlorophenol	ND <	0.20	mg/Kg	24-FEB-95	28-FEB-95
-					
Surrogate:					
2-Fluorophenol	68.0	-	%	24-FEB-95	28-FEB-95
Phenol-d5	78.9	-	%	24-FEB-95	28-FEB-95
Nitrobenzene-d5	96.8	-	%	24-FEB-95	28-FEB-95
2-Fluorobiphenyl	84.9	-	%	24-FEB-95	28-FEB-95
2,4,6-Tribromophenol	89.7	-	%	24-FEB-95	28-FEB-95
Terphenyl-d14	67.6	-	%	24-FEB-95	28-FEB-95
2-Chlorophenol-d4	79.8	-	%	24-FEB-95	28-FEB-95
1,2-Dichlorobenzene-d4	49.3	-	%	24-FEB-95	28-FEB-95
-					

## Comments:

The presence of Di-n-butyl phthalate may be due to a laboratory contamination.  
 The report DL's for some compounds are higher due to matrix interferences.

## GC/MS Semi-Quantitative

UNDECANE	8.0	0.20	mg/Kg	24-FEB-95	28-FEB-95
6-Methyl-Dodecane	3.0	0.20	mg/Kg	24-FEB-95	28-FEB-95
2-Methylundecane	3.0	0.20	mg/Kg	24-FEB-95	28-FEB-95
ALKANES	15.	0.20	mg/Kg	24-FEB-95	28-FEB-95
2,6,8-Trimethyldecane	4.0	0.20	mg/Kg	24-FEB-95	28-FEB-95
7-Methyltridecane	7.0	0.20	mg/Kg	24-FEB-95	28-FEB-95
TRIDECANE	8.0	0.20	mg/Kg	24-FEB-95	28-FEB-95
5-Methyltridecane	6.0	0.20	mg/Kg	24-FEB-95	28-FEB-95
TETRADECANE	19.	0.20	mg/Kg	24-FEB-95	28-FEB-95
2,2'-Diethyl-1,1'-Biphenyl	11.	0.20	mg/Kg	24-FEB-95	28-FEB-95
(E)-3-Eicosene	2.0	0.20	mg/Kg	24-FEB-95	28-FEB-95

## SEM Laboratories

## ANALYTICAL DATA REPORT

Prepared for: Demco & Moore-Phoenix  
 Project Id: 27341-005-153 Orchids Paper Phase II  
 Sample Id: A  
 Lab Id: L9502231-1

Collected: 22-FEB-95  
 Received: 23-FEB-95  
 Reported: 13-MAR-95

## Semi-Volatile Organic Compounds by GC/MS

Compound	Conc	Unit	24-FEB-95	28-FEB-95
4-Chloro-3-Methylphenol	ND	< 0.20	mg/Kg	24-FEB-95
2-Chlorophenol	ND	< 0.20	mg/Kg	24-FEB-95
2,4-Dichlorophenol	ND	< 0.20	mg/Kg	24-FEB-95
2,4-Dimethylphenol	ND	< 0.20	mg/Kg	24-FEB-95
2,4-Dinitrophenol	ND	< 1.0	mg/Kg	24-FEB-95
2-methyl-4,6-dinitrophenol	ND	< 1.0	mg/Kg	24-FEB-95
2-Nitrophenol	ND	< 0.20	mg/Kg	24-FEB-95
4-Nitrophenol	ND	< 1.0	mg/Kg	24-FEB-95
Pentachlorophenol	ND	< 1.0	mg/Kg	24-FEB-95
Phenol	0.74	0.20	mg/Kg	24-FEB-95
2,4,6-Trichlorophenol	ND	< 0.20	mg/Kg	24-FEB-95
Acenaphthene	ND	< 0.20	mg/Kg	24-FEB-95
Acenaphthylene	ND	< 0.20	mg/Kg	24-FEB-95
Anthracene	ND	< 0.20	mg/Kg	24-FEB-95
Benzo(a)Anthracene	ND	< 2.0	mg/Kg	24-FEB-95
Benzo(b)Fluoranthene	ND	< 2.0	mg/Kg	24-FEB-95
Benzo(k)Fluoranthene	ND	< 2.0	mg/Kg	24-FEB-95
Benzo(a)Pyrene	ND	< 2.0	mg/Kg	24-FEB-95
Benzo(g,h,i)Perylene	ND	< 2.0	mg/Kg	24-FEB-95
Benzidine	ND	< 10	mg/Kg	24-FEB-95
Bis(2-Chloroethyl)Ether	ND	< 0.20	mg/Kg	24-FEB-95
Bis(2-Chloroethoxy)Methane	ND	< 0.20	mg/Kg	24-FEB-95
Bis(2-ethylhexyl)phthalate	ND	< 2.0	mg/Kg	24-FEB-95
Bis(2-Chloroisopropyl)ether	ND	< 0.20	mg/Kg	24-FEB-95
4-Bromophenyl Phenyl Ether	ND	< 0.20	mg/Kg	24-FEB-95
Butyl Benzyl Phthalate	ND	< 2.0	mg/Kg	24-FEB-95
2-Chloronaphthalene	ND	< 0.20	mg/Kg	24-FEB-95
4-Chlorophenyl Phenyl Ether	ND	< 0.20	mg/Kg	24-FEB-95
Chrysene	ND	< 2.0	mg/Kg	24-FEB-95
Dibenzo(a,h)Anthracene	ND	< 2.0	mg/Kg	24-FEB-95
Di-n-Butyl Phthalate	0.28	0.20	mg/Kg	24-FEB-95
1,2-Dichlorobenzene	ND	< 0.20	mg/Kg	24-FEB-95
1,3-Dichlorobenzene	ND	< 0.20	mg/Kg	24-FEB-95
1,4-dichlorobenzene	ND	< 0.20	mg/Kg	24-FEB-95
3,3'-Dichlorobenzidine	ND	< 5.0	mg/Kg	24-FEB-95
Diethyl Phthalate	ND	< 0.20	mg/Kg	24-FEB-95
Dimethyl Phthalate	ND	< 0.20	mg/Kg	24-FEB-95
2,4-Dinitrotoluene	ND	< 0.20	mg/Kg	24-FEB-95
2,6-Dinitrotoluene	ND	< 0.20	mg/Kg	24-FEB-95
Di-n-Octyl Phthalate	ND	< 2.0	mg/Kg	24-FEB-95
Fluoranthene	ND	< 0.20	mg/Kg	24-FEB-95
Hexachlorobenzene	ND	< 0.20	mg/Kg	24-FEB-95
Hexachlorobutadiene	ND	< 0.20	mg/Kg	24-FEB-95
Hexachlorocyclopentadiene	ND	< 0.20	mg/Kg	24-FEB-95
Hexachlorocyclopentadiene	ND	< 1.0	mg/Kg	24-FEB-95
Indeno(1,2,3-cd)Pyrene	ND	< 2.0	mg/Kg	24-FEB-95
Isophterene	ND	< 0.20	mg/Kg	24-FEB-95
Naphthalene	ND	< 0.20	mg/Kg	24-FEB-95
Nitrobenzene	ND	< 0.20	mg/Kg	24-FEB-95
N-Nitroso-dimethylamine	ND	< 0.20	mg/Kg	24-FEB-95
N-Nitroso-di-n-Propylamine	ND	< 0.20	mg/Kg	24-FEB-95
N-Nitroso-diphenylamine	ND	< 0.20	mg/Kg	24-FEB-95
Phenanthrene	ND	< 0.20	mg/Kg	24-FEB-95
Pyrene	ND	< 2.0	mg/Kg	24-FEB-95
1,2,4-Trichlorobenzene	ND	< 0.20	mg/Kg	24-FEB-95
Aniline	ND	< 0.20	mg/Kg	24-FEB-95



11-14-94  
DATE

November 14, 1994

Project No. 934X246A-EA02

Mr. Ben Fisk  
City of Flagstaff  
211 West Aspen  
Flagstaff, AZ 86001

EVALUATION OF PAPER  
SLUDGE ANALYTICAL RESULTS  
ORCHIDS PAPER MILL  
FLAGSTAFF, ARIZONA

Dear Mr. Fisk:

Woodward-Clyde Consultants (WCC) is pleased to provide the City of Flagstaff (City) this letter summarizing our evaluation of analytical results provided for paper sludge generated by the Orchids Paper Mill (Orchids Paper), located in Flagstaff, Arizona.

**BACKGROUND**

The City has been leasing property known as the Cinder Lake Landfill from the U.S. Forest Service for use as a municipal landfill for the City, Coconino County and the surrounding area. It is our understanding that the City has been accepting paper waste sludge at the Cinder Lake Landfill from Orchids Paper for a number of years; recently shipments of this material to the landfill have been segregated and stockpiled at a location separate from other accepted municipal waste.

Analyses of the paper waste sludge were conducted by American Analytical Laboratories of Phoenix, Arizona in December 1993 and February 1994. The laboratory is no longer in business and it is currently under investigation by the state.

**SCOPE OF SERVICES**

Based on our proposal dated July 15, 1994, WCC conducted the following tasks:

- Evaluate whether the paper sludge is acceptable at the landfill based on a review of the data provided by the City
- Indicate whether there are additional analyses that are required to identify whether or not the paper sludge can be landfilled at the Cinder Lake Landfill

Mr. Ben Fisk  
City of Flagstaff  
November 14, 1994  
Page 2

## REGULATORY REVIEW

### Waste Characterization Criteria

WCC has reviewed the Federal Register, 40 CFR Chapter I, Part 261 Subparts A through D to identify whether the paper sludge can be considered a RCRA hazardous waste. This solid waste is a RCRA hazardous waste, if it is: 1) ignitable, 2) corrosive, 3) reactive, 4) toxic or 5) a listed hazardous waste (see Subpart D).

Toxicity of a solid waste is evaluated by subjecting the solid waste to the Toxicity Characteristic Leaching Procedure (TCLP) and analyzing the resulting extract for the constituents listed in Table 1. If the concentration in the extract exceeds the TCLP regulatory level for any of the constituents listed in Table 1, the solid waste is considered a RCRA hazardous waste.

### Evaluation of Laboratory Data

Laboratory analytical results for the paper sludge are summarized in Table 1. Copies of the laboratory analytical data are provided in Attachment A. Based on the results of testing conducted by American Analytical Laboratories, the paper sludge is not ignitable, corrosive or reactive. A review of Subpart D indicates that the paper sludge is not a listed hazardous waste.

Based on the analytical results, none of the constituents analyzed exceeds its respective TCLP regulatory level. However, it should be noted that the paper sludge was subjected to the TCLP and analyzed for nickel and zinc. Nickel and zinc are not listed in "Table 1- Maximum Concentration of Contaminants for the Toxicity Characteristic", 40-CFR, Chapter I, Subpart C. Furthermore, two metals listed in Table 1 (selenium and silver) were not analyzed. Additional compounds not analyzed included the pesticides chlordane, Endrin, heptachlor, methoxychlor, and toxaphene, the herbicides 2,4-D and 2,4,5-TP (Silvex), and the base-neutral extractable volatile organic compound hexachloroethane. No analytical results have been provided for dioxin.

## RECOMMENDATIONS

Based on WCC's review of the existing data and regulatory information, we recommend that the City of Flagstaff take the following actions:

- Request Orchids Paper to conduct analyses for the additional contaminants listed above that were not included in the laboratory results provided to WCC.

Mr. Ben Fisk  
City of Flagstaff  
November 14, 1994  
Page 3

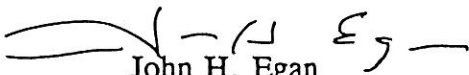
Following completion of analyses for the remaining TCLP contaminants, WCC will evaluate the additional laboratory data to identify whether the paper sludge is a hazardous waste. As stated in 40CFR 261.11, it is the generator's responsibility to determine whether its waste exhibits one or more of the characteristics characterizing a solid waste as a RCRA hazardous waste. If the materials are characterized as a RCRA hazardous waste, we recommend that no further acceptance of these materials be permitted at the landfill. If analyses indicate that the materials exceed TCLP regulatory levels, the materials should be removed from the premises and be disposed in accordance with regulatory requirements.

- Orchids Paper should notify the City if and when the waste generating process changes. If the process has changed, a sample of the waste should be analyzed for the entire suite of TCLP contaminants, and based on the results, the City should take action as necessary. It is important that the records of changes in the waste generating process be maintained.

If you have any questions regarding this issue, please call the undersigned.

Very truly yours,

WOODWARD-CLYDE CONSULTANTS

  
John H. Egan  
Vice President

JHE/RKS/sll

Attachment


  
Robert K. Scott  
Project Geologist

TABLE 1

HAZARDOUS WASTE CHARACTERIZATION  
PAPER SLUDGE - ORCHIDS PAPER MILL

Characteristic	Contaminant/Parameter	Concentration/ Units	Regulatory Level (mg/l)
Ignitability	Flash point (F)	> 350	< 140
Corrosivity*	----	----	----
Reactivity	pH (unitless)	7.4	< 2 and > 12.5
	cyanide (mg/kg)	0.16	----
Toxicity (mg/l)	Arsenic	< 0.005	5.0
	Barium	1.4	100.0
	benzene	< 0.025	0.5
	cadmium	< 0.0005	1.0
	carbon tetrachloride	< 0.025	0.5
	chlordan	NA	0.03
	chlorobenzene	< 0.025	100.0
	chloroform	< 0.025	6.0
	chromium	0.015	5.0
	o-cresol	< 0.10	200.0
	m-cresol	< 0.10	200.0
	p-cresol	< 0.10	200.0
	cresol	< 0.10	200.0
	2,4-D	NA	10.0
	1,4-dichlorobenzene	< 0.025	7.5
	1,2-dichloroethane	< 0.025	0.5
	1,1-dichloroethylene	< 0.025	0.7
	2,4-dinitrotoluene	< 0.10	0.13
	Endrin	NA	0.02
	Heptachlor	NA	0.008
	hexachlorobenzene	< 0.10	0.13
	hexachlorobutadiene	< 0.10	0.5
	hexachloroethane	NA	3.0
	lead	0.014	5.0
	lindane	NA	0.4
	mercury	< 0.050	0.2
	methoxychlor	NA	10.0
	methyl ethyl ketone	< 0.025	200.0
	nitrobenzene	< 0.10	2.0
	pentachlorophenol	< 0.10	100.0
	pyridine	< 0.10	5.0
	selenium	NA	1.0
	silver	NA	5.0
	tetrachloroethylene	< 0.025	0.7
	toxaphene	NA	0.5
	trichloroethylene	< 0.025	0.5
	2,4,5-trichlorophenol	< 0.10	400.0
	2,4,6-trichlorophenol	< 0.10	2.0
	2,4,5-TP (silvex)	NA	1
	vinyl chloride	< 0.025	0.2

\* Pertains to aqueous waste streams only.

**APPENDIX A**  
**COPIES OF LABORATORY ANALYTICAL DATA**



# American Analytical Laboratories

Tucson — Phoenix — Mexico

## LABORATORY ANALYSIS REPORT

Page 1 of 2

Code: WORENV  
 WORLD ENVIRON. RESEARCH LAB  
 ATTN: JOHN WAGNER  
 1616 EAST MAIN #207  
 MESA, AZ 85203-

**SAMPLE INFORMATION**  
 Sample...: 017942-01  
 Clnt Smp:  
 Descript: PAPER SLUDGE  
 Location: ORCHIDS PAPER MILL  
 Samp D/T: / /  
 Sampler.: CLIENT  
 Trans By: C. CRAWFORD  
 Recvd By: R. DIXON  
 Date Rcv: 02/01/94  
 Date Rpt: 02/23/94

Analysis	MCL	Results	Date
35.2 CYANIDES, TOTAL		0.16 MG/KG	02/14/94
1010 FLASH POINT - PM - DEG. F		NO FLASH TO 350	02/14/94
DIOXIN LOW RESOLUTION GC/MS BY 613		TO FOLLOW	02/14/94
095 PAINT FILTER LIQUIDS TEST		0 %	02/14/94
150.1 PH (ELECTROM.) STANDARD UNITS		7.4	02/02/94
20.1 PHENOLS (COLORIMETRIC)		<0.05 *	02/08/94
CLP M TCLP METALS			02/10/94
1. NICKEL		0.009	
2. ZINC		0.549	
CLP S.VOL TCLP SEM VOL			02/17/94
1,4-DICHLOROBENZENE		<0.025	
2,4,5-TRICHLOROPHENOL		<0.10	
2,4,6-TRICHLOROPHENOL		<0.10	
2,4-DINITROTOLUENE		<0.10	
CRESOL (TOTAL)		<0.10	
HEXACHLOROBENZENE		<0.10	
HEXACHLOROBUTADIENE		<0.10	
M-CRESOL (3-METHYLPHENOL)		<0.10	

### Comments:

All units are MG/L unless otherwise specified.  
 ND means analyte not detected.  
 MDL is the Method Detection Limit.

  
 Analyst(s)



# American Analytical Laboratories

Tucson — Phoenix — Mexico

## LABORATORY ANALYSIS REPORT

Page 2 of 2

Code: WORENV  
WORLD ENVIRON. RESEARCH LAB  
ATTN: JOHN WAGNER  
616 EAST MAIN #207  
MESA, AZ 85203-

**SAMPLE INFORMATION**  
Sample...: 017942-01  
Clnt Smp:  
Descript: PAPER SLUDGE  
Location: ORCHIDS PAPER MILL  
Samp D/T: / /  
Sampler.: CLIENT  
Trans By: C. CRAWFORD  
Recvd By: R. DIXON  
Date Rcv: 02/01/94  
Date Rpt: 02/23/94

### Analysis

### MCL

### Results

### Date

NITROBENZENE  
O-CRESOL (2-METHYLPHENOL)  
P-CRESOL (4-METHYLPHENOL)  
PENTACHLOROPHENOL  
PYRIDINE  
TCLP VOC  
1,1-DICHLOROETHENE  
1,2-DICHLOROETHANE (EDC)  
BENZENE  
CARBON TETRACHLORIDE  
CHLOROBENZENE  
CHLOROFORM  
METHYL ETHYL KETONE  
TETRACHLOROETHENE (PCE)  
TRICHLOROETHENE (TCE)  
VINYL CHLORIDE


<0.10  
<0.10  
<0.10  
<0.10  
<0.10

<0.025  
<0.025  
<0.025  
<0.025  
<0.025  
<0.025  
<0.025  
<0.025  
<0.025  
<0.025

02/11/94

### Comments:

All units are MG/L unless otherwise specified.  
ND means analyte not detected.  
MDL is the Method Detection Limit.

  
Analyst(s)



# American Analytical Laboratories

Tucson — Phoenix — Mexico

## LABORATORY ANALYSIS REPORT

Page 1 of 1

Code: ORHPAP  
ORHID PAPER PRODUCTS  
ATTN: JAMES ANGLIN  
124 NORTH 67TH ST. #112  
MESA, AZ 85205-

**SAMPLE INFORMATION**  
Sample...: 017270-01  
Clnt Smp:  
Descript: PAPER SLUDGE  
Location:  
Samp D/T: / /  
Sampler.: CLIENT  
Trans By: CERRY CRAWFORD  
Recvd By: REBECCA DIXON  
Date Rcv: 12/10/93  
Date Rpt: 12/17/93

### Analysis

### MCL

### Results

### Date

13.1 MOD OIL & GREASE MODIFIED  
1311TM TCLP METALS  
ARSENIC  
BARIUM  
CADMIUM  
CHROMIUM  
LEAD  
MERCURY

<20 MG/KG

12/13/93

12/14/93

<0.005

1.40

<0.0005

0.015

0.014

<0.050

### Comments:

All units are MG/L unless otherwise specified.

ND means analyte not detected.

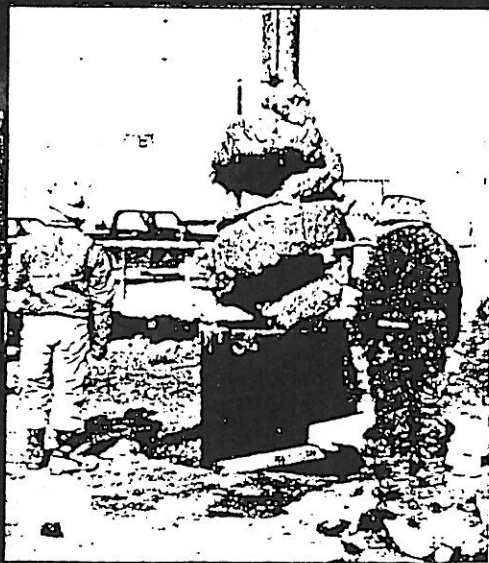
MDL is the Method Detection Limit.

*[Signature]*  
Analyst(s)

## **APPENDIX C**

JUL. 1997 VOL. 123 NO. 7  
ISSN 1090-0241  
CODEN: JGGEFK

# JOURNAL OF GEOTECHNICAL and GEOENVIRONMENTAL ENGINEERING



## TECHNICAL PAPERS

- Study of Rock Fracture by  
Permeability Method  
Akai B. Singh 601
- Modeling of Dilative Shear Failure  
X. S. Li 609
- Performance of Excavations  
for Depressed Expressway  
in Singapore  
Ing Hieng Wong, Teoh Yaw Poh,  
and Han Leong Chuah 617
- Analysis of Stress-Change  
Disturbance Caused by  
Ideal Drilling in Clay  
X. S. Li, J. Holland,  
G. Wang, and C. J. Roblee 626
- Modified Newmark Model for  
Seismic Displacements of  
Compliant Slopes  
Steven L. Kramer and  
Matthew W. Smith 635
- Hydrate Melting in Soil  
around Hot Conductor  
Jean-Louis Briaud  
and Adel Chaouh 645
- Laboratory and Field Hydraulic  
Conductivity of Three  
Compacted Paper Mill Sludges  
Jason F. Kraus, Craig H. Benson,  
C. Van Maltby, and X. Wang 654
- Subgrade Resilient Modulus  
Correction for Saturation Effects  
Eric C. Drumm, Jason S. Reeves,  
Mark R. Madgett, and  
William D. Trolinger 663
- Effects of Initial Density on Soil  
Instability at High Pressures  
Paul A. Bopp and Poul V. Lade 671

## DISCUSSIONS

- Nonlinear Lateral Pile Deflection  
Prediction in Sands.  
Shamsher Prakash  
and Sanjeev Kumar.  
By M. Maugeri and F. Castelli.  
Closure by authors 679
- Determination of Drained Friction  
Angle of Sand from CPT.  
J. W. Chen and C. H. Juang  
By Branko Ladanyi.  
Closure by authors 680

**ASCE**

*The Geo-Institute of the  
American Society of Civil Engineers*

# LABORATORY AND FIELD HYDRAULIC CONDUCTIVITY OF THREE COMPACTED PAPER MILL SLUDGES

By Jason F. Kraus,<sup>1</sup> Craig H. Benson,<sup>2</sup> Associate Member, ASCE,  
C. Van Maltby,<sup>3</sup> and X. Wang<sup>4</sup>

**ABSTRACT:** Hydraulic conductivities of three compacted paper mill sludges were measured in various ways to assess their viability for use in barrier layers in landfill final covers. Compaction tests showed that the sludges have compaction curves similar to those for clays, albeit with lower maximum dry unit weights and higher optimum water contents. Hydraulic conductivities less than  $1 \times 10^{-9}$  m/s can be attained for these sludges at low effective stresses (<10 kPa) when compacted using standard Proctor energy if the molding water content is 50–100 percentage points greater than optimum water content. The lowest hydraulic conductivities were obtained in this range. At higher effective stresses (>20 kPa), hydraulic conductivities less than  $1 \times 10^{-9}$  m/s can be achieved at higher molding water contents. Field tests conducted on barrier layers constructed with two of the sludges showed that field hydraulic conductivities can be obtained that are similar to those measured on laboratory compacted specimens prepared at the same molding water content. Laboratory tests on large and small undisturbed specimens removed from the field showed that no scale dependence existed in the hydraulic conductivity of the field compacted sludge. Additional tests showed that freezing increased the hydraulic conductivity of two of the sludges, regardless of whether the sludges were permeated between freeze-thaw cycles or only after the last thaw. In contrast, for the third sludge, increases in hydraulic conductivity only occurred if the sludge was not permeated between freeze-thaw cycles. Significant shrinkage and cracking of the sludges occurred when they were dried, suggesting that barrier layers constructed with sludge should not be permitted to desiccate. Long-term tests showed that the hydraulic conductivity remains stable or decreases slowly if permeation is continued over an extended period of time.

## INTRODUCTION

Large quantities of pulp and paper mill sludge are generated each year by wastewater-treatment plants operated by the paper industry. In the past, nearly all of the sludge was landfilled. However, with the advent of increased environmental regulation and the increasing cost of solid waste disposal, the paper industry has been searching for beneficial ways to use its sludge. Because some paper mill sludges have been shown to possess engineering properties similar to clays, interest has developed in using sludges for construction of barrier layers in landfill final covers (National 1989; Genthe 1993; Moo-Young 1992; Zimmie et al. 1993; Floess et al. 1995; Moo-Young and Zimmie 1996a). This application has the potential to use large quantities of sludge and may be particularly advantageous to landfill operators in regions where paper mills exist and clay borrow sources are scarce or more costly.

In this study, hydraulic properties relevant to landfill cover design were assessed for three sludges. Each sludge is being considered for use in constructing barrier layers in final covers. Two of the sludges are from mills in Michigan; the third sludge is from a mill in Massachusetts.

## BACKGROUND

The use of paper mill sludges in landfill construction was initially investigated by Stoffel and Ham (1979) and Pepin (1984). Based on these promising studies, the National Coun-

cil of the Paper Industry for Air and Stream Improvement (NCASI) undertook a study investigating the hydraulic properties of a variety of sludges and sludge-fly ash mixtures. Hydraulic conductivity tests were conducted on 15 paper mill sludges of various origins (National 1989). The specimens were compacted at their as-received water contents (120–409%) using standard Proctor procedures (ASTM D 698), except that only 10 blows were applied per lift. Rigid-wall compaction-mold permeaters were used for hydraulic conductivity testing. The resulting hydraulic conductivities ranged from  $4.2 \times 10^{-6}$  to  $5.8 \times 10^{-10}$  m/s. The low hydraulic conductivity obtained for some of the paper mill sludges suggested that some sludges may be viable for use in constructing barrier layers, which generally are required to have hydraulic conductivity less than  $1 \times 10^{-9}$  m/s.

Zimmie et al. (1993) examined the geotechnical properties of a paper mill sludge from Erving Paper Co. in Massachusetts. Compaction, hydraulic conductivity, consolidation, and shear-strength tests were performed. The effects that freeze-thaw and effective stress have on the hydraulic conductivity of the sludge were also examined.

Zimmie et al. developed a compaction curve for the sludge by gradually drying it from its as-received water content and compacting specimens on grab samples removed as drying occurred. Standard Proctor compactive effort (ASTM D 698) was employed. Zimmie et al. reported that the compaction curve for Erving paper mill sludge was similar in shape to curves typical of compacted clays. However, the maximum dry unit weight was lower and the optimum water content was higher relative to those for compacted clays. Some of the compacted specimens were permeated in flexible-wall permeaters to determine the relationship between hydraulic conductivity and molding water content. The hydraulic conductivity was found to be much lower (two orders of magnitude) for specimens compacted at water contents wet of optimum, relative to those compacted near optimum water content (Fig. 1).

Zimmie et al. also performed hydraulic conductivity tests on specimens removed from the barrier layer of a landfill cover constructed with the same paper mill sludge. Fourteen specimens were removed using thin-wall sampling tubes (di-

<sup>1</sup>Geoenviron. Engr., CH2M Hill, Inc., Salt Lake City, UT 84107.

<sup>2</sup>Assoc. Prof., Dept. of Civ. and Envir. Engrg., Univ. of Wisc., Madison, WI 53706.

<sup>3</sup>Res. Sci., Nat. Council of the Pulp and Paper Industry for Air and Stream Improvement, Kalamazoo, MI 49008.

<sup>4</sup>Geotech. Lab. Mgr., Dept. of Civ. and Envir. Engrg., Univ. of Wisc., Madison, WI.

Note. Discussion open until December 1, 1997. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on December 27, 1995. This paper is part of the *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 123, No. 7, July, 1997. ©ASCE, ISSN 1090-0241/97/0007-0654-0662/\$4.00 + \$.50 per page. Paper No. 12277.

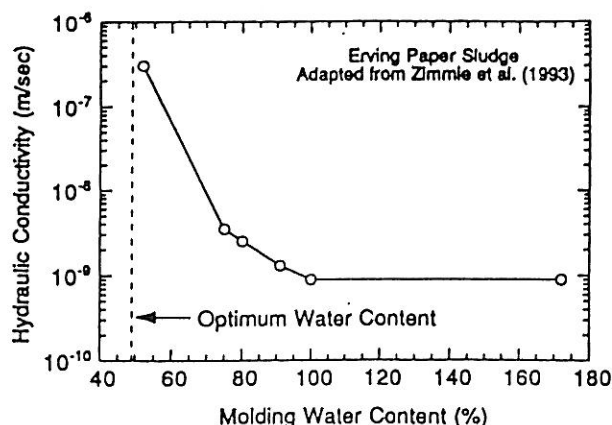


FIG. 1. Hydraulic Conductivity versus Molding Water Content for Erving Paper Sludge (adapted from Zimmie et al. 1993)

ameter = 71 mm) and permeated in flexible-wall permeameters using a confining stress of 34.5 kPa and hydraulic gradient of 21. Three specimens collected immediately after construction had hydraulic conductivities between  $10^{-9}$  and  $10^{-8}$  m/s. The remaining 11 specimens were removed from the landfill at least three months after construction and all had hydraulic conductivity  $< 1 \times 10^{-9}$  m/s. Zimmie et al. suggest that the specimens collected later had lower hydraulic conductivity because of consolidation of the sludge.

To evaluate how freeze-thaw affects the hydraulic conductivity of paper mill sludge, Zimmie et al. compacted specimens at a water content of 170% (120 percentage points wet of optimum) using standard Proctor effort. After compaction, the specimens were wrapped in plastic to prevent desiccation and were frozen one-dimensionally. Once the desired number of freeze-thaw cycles was attained, the specimens were placed in flexible-wall permeameters and permeated at effective stresses of 34, 69, and 138 kPa using a hydraulic gradient of 21. The hydraulic conductivity of the sludge increased approximately one order of magnitude after 10 freeze-thaw cycles. Similar increases in hydraulic conductivity occurred at each effective stress. However, increasing the effective stress from 34 to 138 kPa decreased the hydraulic conductivity of the sludge approximately one order of magnitude at each freeze-thaw cycle. Moo-Young and Zimmie (1996b) reported similar results.

Maltby and Eppstein (1994) describe a field study in which paper mill sludges were used in landfill cover test cells. The

field study was undertaken to compare the performance of barrier layers constructed with paper mill sludge and compacted clay. One of the two test cells containing paper mill sludge was constructed with a combined sludge and the other was constructed with a primary sludge. Two other test cells were constructed using compacted clay. Construction of the test cells was completed in November 1987. A schematic of the test cells is shown in Fig. 2. Each test cell was 8.4 m  $\times$  8.4 m in areal extent.

Comparisons of tests cells were based on water balance computations (e.g., runoff, soil water storage, percolation, etc.). After five years, Maltby and Eppstein (1994) observed that: (1) the test cells constructed with sludge consolidated more than those constructed with clays; (2) the cells containing sludge had greater amounts of runoff than the cells constructed with clay; (3) percolation was lower for the cells containing paper mill sludge; and (4) the field hydraulic conductivities of the barrier layers constructed with sludge were lower than those containing compacted clay ( $4 \times 10^{-10}$  and  $1 \times 10^{-9}$  m/s for the cells containing sludge;  $1 \times 10^{-8}$  m/s for both cells containing compacted clay).

Another factor that must be considered when using sludge as an alternative to compacted clay is the quality of leachate produced as water percolates through the barrier layer. NCASI (1992) compared leachate from paper mill sludge landfills to leachate from municipal solid waste landfills. They found that paper mill sludge leachates contain a variety of inorganic and organic compounds, including heavy metals and volatile organic compounds. However, the concentration of these compounds were rarely found to exceed concentrations typically found in municipal solid waste leachate. Thus, using paper mill sludge in final covers should not introduce additional environmental risks beyond those already imposed by a typical municipal solid waste landfill.

## SLUDGES USED IN THIS STUDY

Three paper mill sludges were used in the testing program, referred to here as Sludges A, B, and C. Sludge A is a combined sludge that is composed of primary sludge from clarification of raw wastewater and biological sludge from biological treatment. Sludge A is from a nonintegrated mill that produces specialty grades and coated and uncoated book grades of paper. Sludge B is a primary sludge from a nonintegrated mill that produces specialty coated, lightweight coated, coated bag, and pressure sensitive paper. Sludges A

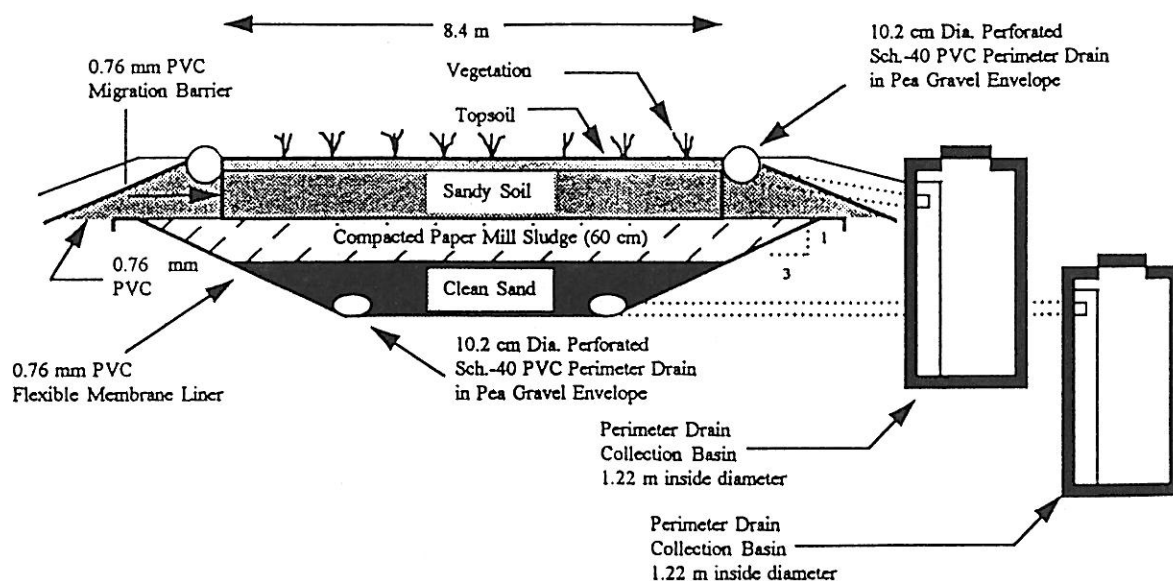


FIG. 2. Schematic of Test Cell Used in Study Described by Maltby and Eppstein (1994)

and B were used to construct the test cells described in Maltby and Eppstein (1994). Sludge C is a combined sludge from a de-inking mill that produces disposable garments, and napkin and tissue paper. Sludges A and B are from paper mills in Michigan; Sludge C is from a paper mill in Massachusetts.

Bulk samples of the sludges were supplied by the NCASI office in Kalamazoo, Michigan. The sludges were stored in a refrigerated warehouse prior to use so that biological activity would not change their properties during the testing program. A photograph showing a grab sample of Sludge B is shown in Fig. 3(a). The sludges are white or gray, have water contents ranging from 150 to 260%, and are soft and compressible. Each sludge contains a large quantity of small, cellulosic fibers [Fig. 3(b)].

Unsuccessful attempts were made to determine the liquid and plastic limits of the three sludges. For the liquid limit test, a smooth groove could not be cut in the sludge. Instead, the sludge appeared to tear as it was grooved. Apparently, the fibers in the sludge [Fig. 3(b)] were responsible for this behavior. Plastic limit tests also proved unsuccessful. Similar difficulties with Atterberg limit tests on paper mill sludge have been reported by NCASI (1989) and Genthe (1993). However, Zimmie et al. (1993) were successful in measuring the liquid and plastic limits of the Erving sludge. Nevertheless, because most paper mill sludges are fibrous, it seems that the Atterberg limits are not useful indices for characterizing sludges. Moo-Young and Zimmie (1996a) have drawn a similar conclusion.

Tests were also conducted to determine the ash content, percent fines, and weighted average fiber length for each sludge. The ash contents were measured using procedures described

TABLE 1. Index Properties of Sludges

Sludge (1)	Fines (%) (2)	Two-micron clay fraction (%) (3)	Ash content (%) (4)	Average fiber length (mm) (5)
A	59	41	56	0.24
B	76	23	53	0.12
C	80	36	44	0.29

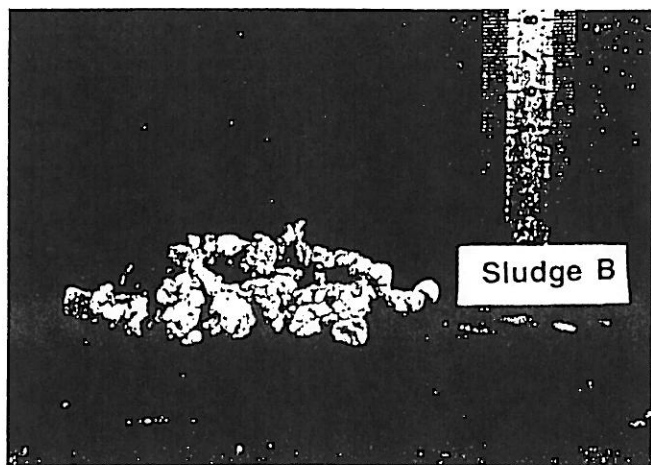
in ASTM D 2974. Wash sieving past the No. 200 sieve was used to determine the percent fines and sedimentation was used to determine the two-micron clay fraction following ASTM D 422. Technical Association of the Pulp and Paper Industry (TAPPI) T233 was used to measure the average fiber length (Technical 1992). Sieve analyses were not conducted on the material retained on the No. 200 sieve because it was fibrous, organic matter not amenable to sieving. Results of the tests are summarized in Table 1.

## COMPACTION

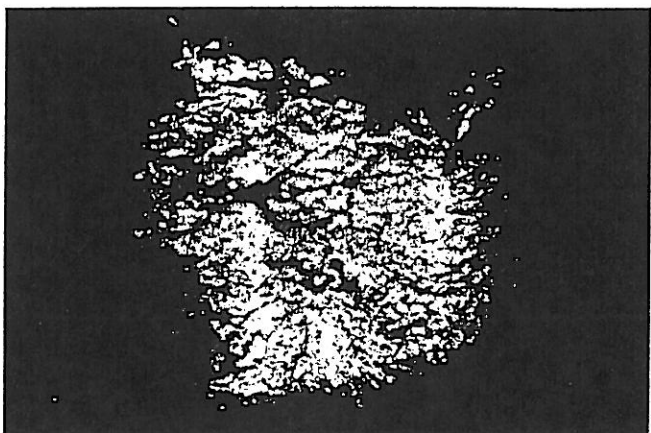
Compaction tests were conducted on the three sludges to determine the relationship between dry unit weight and molding water content. Standard Proctor compactive effort was used (ASTM D 698). Prior to compaction, the sludge was allowed to air dry from its "as-received" water content (i.e., water content of sludge when received at the University of Wisconsin). At various times, a grab sample was taken, sealed in a plastic bag or bucket, and allowed to equilibrate at least 24 h prior to compaction. This method was used because previous studies have shown that completely air-dried sludge forms a hard aggregate that cannot be rewetted into a remoldable, plastic material (NCASI 1989; Zimmie et al. 1993). Water content measurements were measured for each compacted specimen by drying in an oven at 70°C. A lower temperature was used to prevent burning of organic matter.

Results of the compaction tests are shown in Fig. 4. The sludges have compaction curves similar to those typical of clays [e.g., Mitchell et al. (1965)]. However, the optimum water contents are higher (40–60%) in comparison to typical optimum water contents for clays, and the maximum dry unit weights (6.0–8.7 kN/m<sup>3</sup>) are lower than those for clays. Furthermore, for each sludge, optimum water content is markedly lower than the as-received water content. These findings are consistent with those reported by Zimmie et al. (1993) and Zimmie and Moo-Young (1995).

The macrostructure of the compacted specimens (Fig. 5) also appeared similar to the structure observed in compacted clays. Dry of optimum water content, the sludge formed hard



(a)



(b)

FIG. 3. Photographs: (a) Grab Sample of Sludge B; (b) Interior of Clod of Sludge B

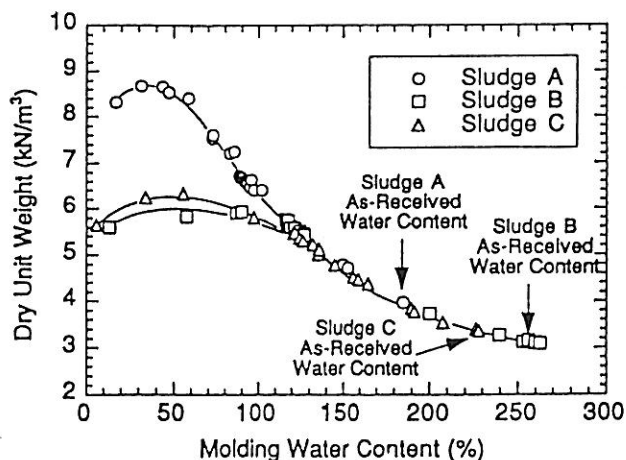
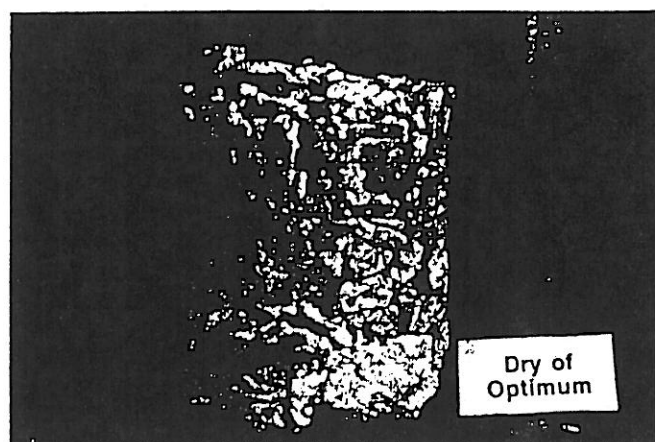
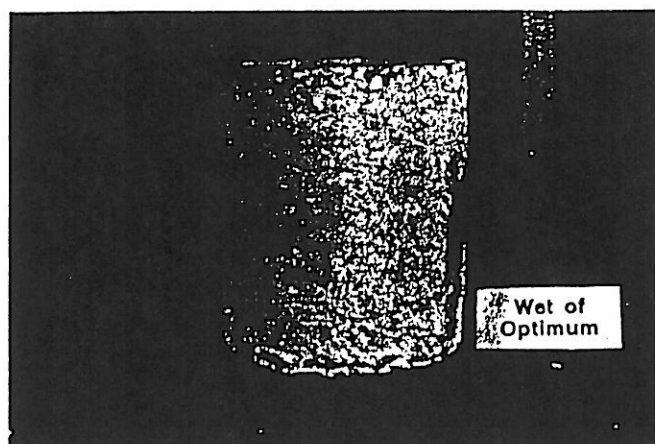


FIG. 4. Compaction Curves for Sludges A, B, and C



(a)



(b)

FIG. 5. Photographs of Compacted Specimens of Sludge B: (a) Dry of Optimum Water Content; (b) Wet of Optimum Water Content

clods that were poorly remolded during compaction. Interclod voids were visible in the specimens compacted dry of optimum water content. In contrast, wet of optimum water content, the clods were soft and readily remolded during compaction, which eliminated large interclod voids. Benson and Daniel (1990) reported similar changes in macrostructure in their study of a compacted highly plastic clay.

## LABORATORY AND FIELD HYDRAULIC CONDUCTIVITY TESTS

### Hydraulic Conductivity-Molding Water Content Relationship

Specimens of the three paper mill sludges were compacted in the laboratory and permeated to determine the relationship between hydraulic conductivity and molding water content. The specimens were permeated in a rigid-wall compaction-mold permeameters equipped with swell rings. The permeameters were essentially the same as those described in Daniel (1994) with a few exceptions. A lead weight was placed on the specimen to simulate an overburden stress of 7 kPa during hydraulic conductivity testing. A disk of nonwoven geotextile overlain by a geonet was placed between the weight and the sludge to ensure that water had free access to the surface of the specimen. Also, a vent tube was installed in the top plate of the permeameter to allow free release of gases generated by decomposition.

The constant headwater-constant tailwater method was used in accordance with methods described in ASTM D 5856. Mariotte bottles were used for the headwater reservoirs. A hy-

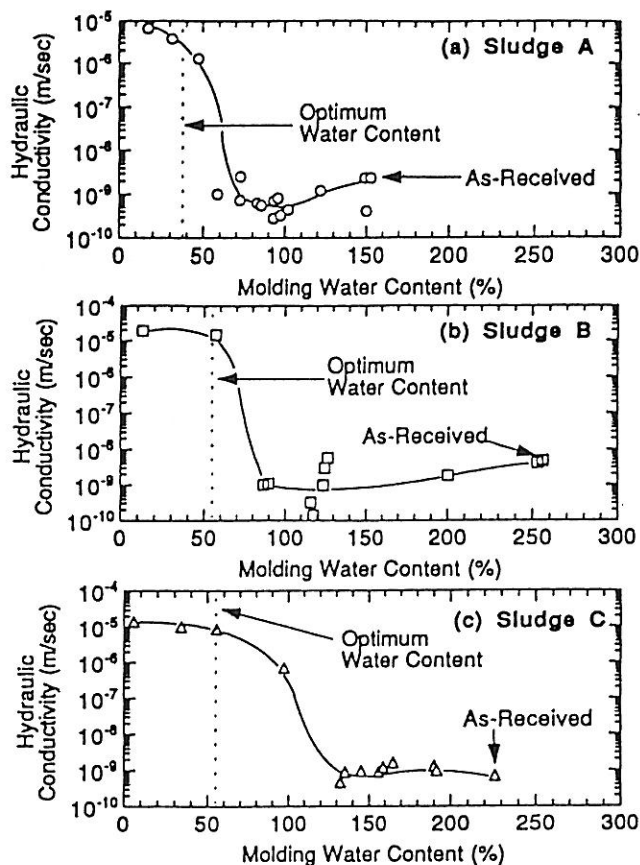


FIG. 6. Hydraulic Conductivity versus Molding Water Content for Sludges A, B, C

draulic gradient of six was applied, and tap water from Madison, Wisconsin, was used as the permeant. Other details of the testing procedure can be found in Kraus (1994).

The relationship between hydraulic conductivity and molding water content for Sludges A, B, and C is shown in Fig. 6. The hydraulic conductivity of each sludge is sensitive to molding water content. Specimens compacted at molding water contents dry of optimum have high hydraulic conductivities, whereas specimens compacted wet of optimum have low hydraulic conductivities. Furthermore, wet of optimum water content, hydraulic conductivities less than  $1 \times 10^{-9}$  m/s were obtained for each sludge with the lowest hydraulic conductivities occurring approximately 50–100% wet of optimum water content. This behavior is similar to that of compacted clays [e.g., Mitchell et al. (1965)], and is consistent with the structural changes shown in Fig. 5. The high percentage of fines and the large clay fraction (Table 1) of the paper mill sludges are likely responsible for the similarity in hydraulic behavior of paper mill sludge and compacted clay.

During permeation, the specimens compacted at the as-received water content consolidated, which resulted in a decrease in length of 30% on average. As a result, their density and stiffness increased, although they never achieved the same density as the specimens that had the lowest hydraulic conductivity (i.e., those compacted approximately 100 percentage points wet of optimum water content, herein referred to as the "Low-K water content"). In contrast, consolidation of the specimens compacted at the Low-K water content was negligible.

### Field Hydraulic Conductivity Tests

Field hydraulic conductivity tests were conducted on the barrier layers of the two test cells described by Maltby and Eppstein (1994) (Fig. 2) using sealed double-ring infiltrome-

ters (SDRIs) and two-stage borehole permeameters (TSBs) when the test cells were decommissioned in the summer of 1995. The barrier layers in the test cells were constructed with Sludges A (combined sludge) and B (primary sludge).

The barrier layers were compacted in two lifts 0.3 m thick, which yielded a total thickness of 0.6 m. The sludges were compacted at their as-received water contents to a dry unit weight comparable to that achieved with standard Proctor effort. During the eight-year span after construction, the barrier layers consolidated approximately 30% (Sludge B) and 35% (Sludge A). Essentially the same amount of consolidation occurred in the laboratory-compacted specimens prepared at their as-received water content. Other details of the construction, instrumentation, and performance of the test sections can be found in Maltby and Eppstein (1994).

#### SDRI Tests

The SDRIs were installed in May 1995 following procedures described in ASTM D 5093. One SDRI was installed in each test cell. The inner rings were 0.9 m wide and the outer rings were 2.4 m wide. Trast and Benson (1995) and Benson et al. (1994) have shown that SDRIs of this size are sufficiently large to accurately measure the field hydraulic conductivity.

Prior to installation, the top soil and silty sand layers (Fig. 2) were removed so that the tests could be conducted directly on the barrier layers. Trenches for the rings were excavated by hand to avoid disturbance of the sludge. Five tensiometers were installed between the inner and outer rings of each SDRI at depths of 0.075, 0.15, 0.23, 0.30, and 0.38 m.

Data were collected from the SDRIs for 50 d. During the first 20 d, gas emanating from the sludges collected in the inner rings of the SDRIs, which resulted in unreliable data. However, after vents were added for purging gas, the infiltration rate was steady. During the entire test period, the tensiometers indicated that matric suction in the sludges was negligible. This occurred because heavy spring rains saturated the barrier layers. In fact, when the surficial soils were stripped from the test cells, standing water existed on the barrier layers.

Hydraulic conductivity ( $K$ ) was computed from infiltration rate ( $I$ ) measured with the SDRIs using

$$K = \frac{I}{i} \quad (1)$$

where  $i$  = hydraulic gradient. Because the barrier layers were saturated and the underlying sand was moist, the hydraulic gradient remained constant at 1.7 throughout the test period. Complete details regarding installation, operation, and data reduction for the SDRIs can be found in Benson and Wang (1996).

#### TSB Tests

The TSBs were installed at the same time as the SDRIs following methods described in Trautwein and Boutwell (1994). Three TSBs were installed in each test cell outside the confines of the SDRI tests. The base of Stage 1 was placed at a depth of 0.2 m (near middepth of barrier layer) and the borehole extensions were 0.1 m long.

Data from the TSBs were collected for 40 d. In the middle of this period, equilibration occurred and Stage 1 was terminated. The boreholes were then extended, and Stage 2 was initiated. Reliable data for both stages were obtained from each of the TSBs installed in Sludge A and one TSB in Sludge B. The other TSBs installed in Sludge B leaked, and thus the data from these TSBs were unreliable.

Data collected from the TSBs were analyzed using the method described in Trautwein and Boutwell (1994). For all of the TSBs, the apparent hydraulic conductivities for Stages

TABLE 2. Summary of Field Hydraulic Conductivities

Test method (1)	Vertical Hydraulic Conductivity (m/s)	
	Sludge A (2)	Sludge B (3)
SDRI	$2 \times 10^{-9}$	$6 \times 10^{-9}$
TSB—1	$3 \times 10^{-9}$	NR
TSB—2	$1 \times 10^{-9}$	$8 \times 10^{-9}$
TSB—3	$2 \times 10^{-9}$	NR
Water balance (Maltby and Eppstein 1994)	$4 \times 10^{-10}$	$1 \times 10^{-9}$

Note: NR = not reported because TSBs leaked.

1 and 2 were practically the same, indicating that the hydraulic conductivity was isotropic. Details regarding installation of the TSBs, the test data, and data analysis procedures can be found in Benson and Wang (1996).

#### Results

Results of the SDRI and TSB tests are summarized in Table 2. For Sludge A, the field hydraulic conductivities range from  $1 \times 10^{-9}$  to  $3 \times 10^{-9}$  m/s and average  $2 \times 10^{-9}$  m/s. The field hydraulic conductivity for Sludge B ranges between  $6 \times 10^{-9}$  and  $8 \times 10^{-9}$  m/s. These hydraulic conductivities are nearly identical to those measured on the laboratory-compacted specimens prepared at their as-received molding water contents (Fig. 6). This suggests that laboratory hydraulic conductivity testing conducted during design on specimens compacted wet of optimum water content may prove useful in field-scale construction of barrier layers constructed with paper mill sludge. In addition, the similarity in field- and laboratory-measured hydraulic conductivities suggests that the barrier layers were not adversely affected by biodegradation of the sludge during their eight-year service life.

#### Tests at Various Effective Stresses

The field hydraulic conductivities measured with the SDRIs and TSBs are higher than those reported by Maltby and Eppstein (1994) using water balance computations (Table 2). One potential cause of this discrepancy is the difference between the effective stress in the barrier layers while the test cells were operational (approximately 18 kPa) and the effective stress existing during field hydraulic conductivity testing ( $\leq 5$  kPa). The effective stress was lower during field testing because the top soil and silty sand layers were removed and, within the SDRIs, the barrier layers were covered with 0.4 m of water. This hypothesis was deemed plausible because the sludges are soft and compressible, and thus their hydraulic conductivity should be sensitive to effective stress. Consequently, tests were performed to determine the relationship between hydraulic conductivity and effective stress on undisturbed specimens removed from the test cells and laboratory-compacted specimens prepared at the Low-K water contents using standard Proctor effort.

Undisturbed specimens were removed from the field in thin-wall sampling tubes (71-mm diameter) and as large undisturbed blocks (0.4 m diameter, 0.4 m height). The specimens removed in tubes were sampled following a method where the tube is displaced using a sharp blow instead of a slow, steady push. The sharp blow shears the fibers in the sludge and results in less disturbance. In contrast, specimens collected using the traditional procedure became disturbed as the fibers in the sludge were dragged along the leading edge of the tube. The specimens removed as blocks were trimmed by hand into polyvinyl chloride rings following procedures described in Othman et al. (1994) and Benson et al. (1995).

All of the specimens were permeated in flexible-wall permeameters. The undisturbed specimens were tested at diameters of 71 mm (tube specimens) and 0.3 m (block specimens). The specimens were initially isotropically consolidated to an effective stress of 5 kPa (field specimens) or 7 kPa (laboratory-compacted specimens). Afterwards, a hydraulic gradient of six was applied. Permeation was continued until a steady hydraulic conductivity was obtained and inflow equaled outflow. The effective stress was then increased by increasing the cell pressure. The specimens were consolidated and permeated until hydraulic conductivities at the desired effective stresses were obtained.

The hydraulic conductivity of all specimens decreased as a result of increasing the effective stress (Fig. 7). The hydraulic conductivity decreased rapidly at lower effective stresses and more slowly at higher effective stresses (i.e.,  $\geq 46$  kPa). Zimmie et al. (1993) and Moo-Young and Zimmie (1996a) report similar behavior for the paper mill sludges they tested. Furthermore, tests on the undisturbed specimens conducted at the lowest effective stress (5 kPa) yielded hydraulic conductivities similar to those measured in the field using the SDRIs and TSBs regardless of whether the specimens were removed in tubes or as large blocks. Thus, the field hydraulic conductivity of the sludges was not scale dependent. Furthermore, when tested at an effective stress representative of the condition existing while the test cells were operational (i.e., 18 kPa), the hydraulic conductivities of the block specimens were nearly identical to the hydraulic conductivities computed by Maltby and Eppstein (1994) using water balance methods (Fig. 7 and Table 2). The writers caution, however, that sludges compacted at low water contents (e.g., dry of optimum water content) may have scale-dependent hydraulic conductivities, as occurs in compacted clays (Benson and Boutwell 1992).

These findings have three practical implications. First, field hydraulic conductivity tests conducted on paper mill sludge may yield hydraulic conductivities higher than those that will exist once the barrier layer consolidates under the overburden stress imposed by overlying soils. Thus, when field tests are used to verify the adequacy of construction methods, the field hydraulic conductivity obtained from such tests must be interpreted with caution or corrected to reflect the appropriate effective stress as suggested by Trast and Benson (1995). Second, laboratory tests should be conducted at effective stresses expected to exist once construction is complete. Otherwise misleading results may be obtained. Third, sufficiently low hydraulic conductivities may be possible with marginal sludges or for sludges having high as-received water content if extra overburden is placed on the sludge.

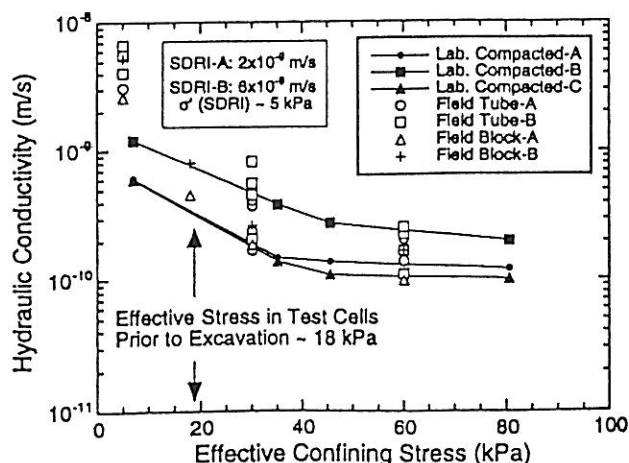


FIG. 7. Hydraulic Conductivity versus Effective Stress for Field and Laboratory-Compacted Specimens

## EVALUATING RESISTANCE TO ENVIRONMENTAL DISTRESS

### Freeze-Thaw

Numerous studies have shown that the hydraulic conductivity of compacted clays increases significantly if the clay freezes (Othman et al. 1994). However, other studies have shown that barriers constructed with bentonite (e.g., geosynthetic clay liners) are not affected by freezing (Shan and Daniel 1991; Kraus et al. 1997; Erickson et al. 1994). One hypothesis for the frost resistance of bentonitic barriers is that the soft bentonite is readily deformed during thawing, which results in closure of the cracks formed during freezing (Kraus 1994). Because many paper mill sludges are soft and compressible, the writers hypothesized that some sludges may also be resistant to increases in hydraulic conductivity caused by freezing.

To evaluate this hypothesis, four specimens of Sludge A and three specimens of Sludges B and C were compacted using standard Proctor effort at the Low-K water contents. Two additional specimens of each sludge were compacted at their as-received water content. The as-received water contents were of interest because it was believed that thaw consolidation might reduce the hydraulic conductivity of these high-water-content sludges. In addition, construction of a barrier layer with sludges at their as-received water content requires less processing than would be required to dry the sludges to the Low-K water content.

The free-standing procedure (Othman et al. 1994) was used to freeze the specimens three-dimensionally in a closed system. A closed system was used to simulate conditions existing in the field where free access to a supply of water is not available during freezing. The specimens were cooled for at least 24 h to an ultimate temperature of  $-20^{\circ}\text{C}$ . After freezing, they were allowed to thaw at room temperature ( $25^{\circ}\text{C}$ ) for 24 h. The thawed specimens were then permeated or placed back in the freezer for another freeze-thaw cycle. This procedure was repeated until the desired number of freeze-thaw cycles was attained.

Flexible-wall permeameters were used to test the frozen and thawed specimens. The falling head-constant tailwater method was used following procedures described in ASTM D 5084. An average effective stress of 10 kPa and hydraulic gradient of six were applied. No backpressure was used.

### Low-K Water Contents

The two specimens of Sludge A prepared at the Low-K water content that were frozen and thawed five times without permeation between freeze-thaw cycles showed an increase in hydraulic conductivity by a factor of 27, on average. In contrast, the two identical specimens permeated prior to freezing and after each freeze-thaw cycle showed a slight decrease in average hydraulic conductivity after exposure to freeze-thaw [Fig. 8(a)].

All of the specimens of Sludge B prepared at the Low-K water content increased in hydraulic conductivity by approximately two orders of magnitude after freeze-thaw [Fig. 8(b)], regardless of whether they were permeated between freeze-thaw cycles. Essentially the same results were obtained for the tests conducted on specimens of Sludge C, except that the increase in hydraulic conductivity for Sludge C was smaller (Kraus 1994).

### As-Received Molding Water Contents

One of the specimens of Sludge A compacted at its as-received water content showed a decrease in hydraulic conductivity after exposure to two or more freeze-thaw cycles.

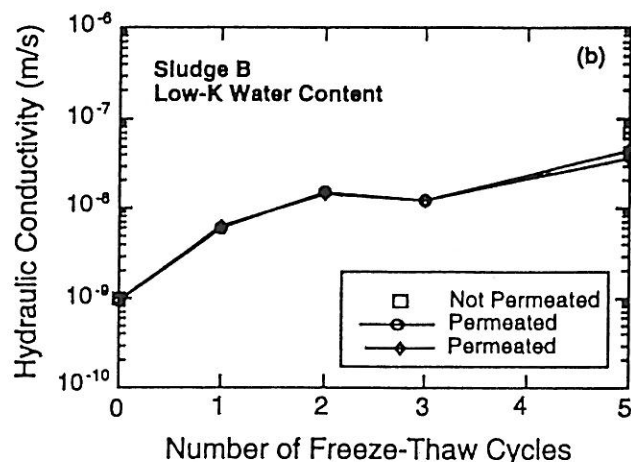
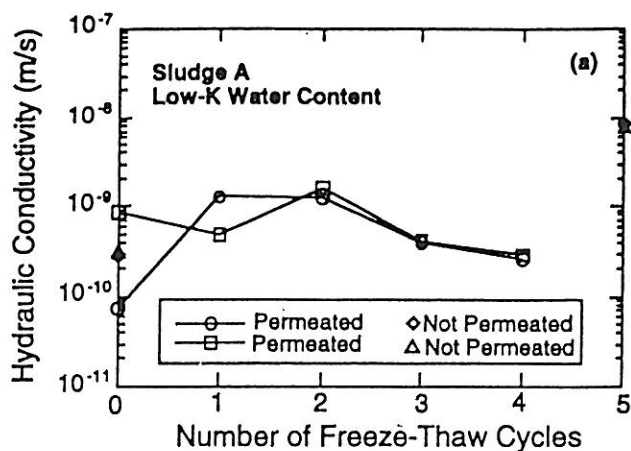


FIG. 8. Hydraulic Conductivity versus Number of Freeze-Thaw Cycles for Specimens Prepared at Low-K Molding Water Content: (a) Sludge A; (b) Sludge B

This specimen was permeated prior to freezing and after each freeze-thaw cycle. The other specimen of Sludge A was permeated after (zero, one, and five freeze-thaw cycles and showed a slight (1.6 times) increase in hydraulic conductivity as a result of freeze-thaw [Fig. 9(a)]. This change in hydraulic conductivity is small relative to that observed for the specimens of Sludge A that were compacted at the Low-K water content and not permeated between freeze-thaw cycles.

The two specimens of Sludge B compacted at the as-received water content were permeated after each freeze-thaw cycle. These specimens had higher initial hydraulic conductivity than the specimens prepared at the Low-K water content but had similar hydraulic conductivity ( $\sim 4.0 \times 10^{-8}$  m/s) after five freeze-thaw cycles [Fig. 9(b)]. Although no tests were conducted on specimens not permeated between freeze-thaw cycles, the writers believe that had tests been conducted, they also would have shown an increase in hydraulic conductivity [e.g., see Fig. 8(b)]. Similar increases in hydraulic conductivity were also observed for the tests conducted with Sludge C on specimens that were and were not permeated between freeze-thaw cycles (Kraus 1994).

#### Structure

The specimens that increased in hydraulic conductivity were cracked as a result of freeze-thaw. These cracks were preferential pathways for flow, which increased the hydraulic conductivity, as has been observed in compacted clays exposed to freeze-thaw cycles (Othman and Benson 1993; Othman et al. 1994). However, the cracks had a different appearance compared to those normally found in compacted clays. Cracks in the sludge formed along boundaries of the sludge clods with-

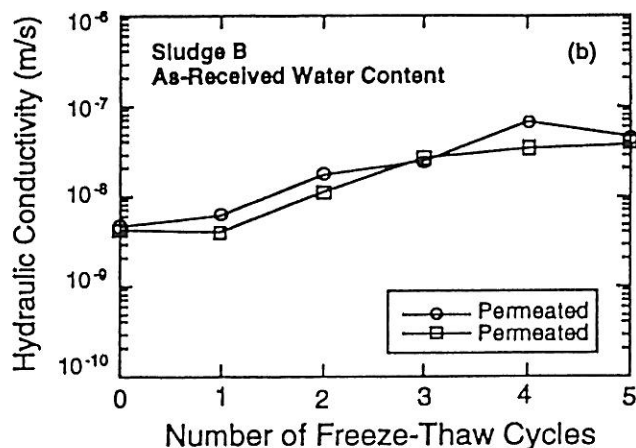
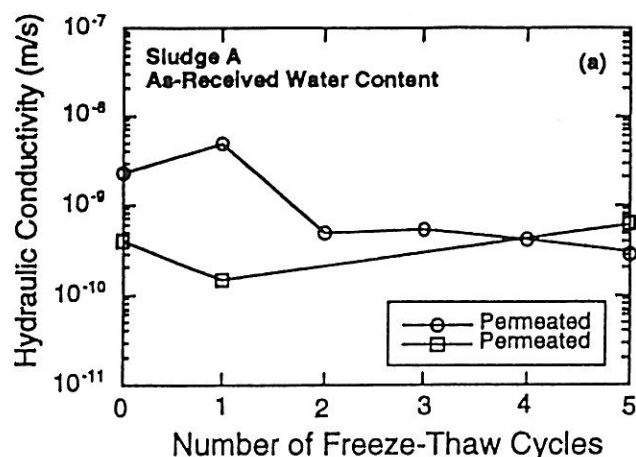


FIG. 9. Hydraulic Conductivity versus Number of Freeze-Thaw Cycles for Specimens Prepared at As-Received Molding Water Content: (a) Sludge A; (b) Sludge B

out a preferential orientation. In contrast, cracks in compacted clays typically are orthogonal, with vertical cracks caused by shrinkage and horizontal cracks formed by ice lenses (Othman and Benson 1993). Moo-Young and Zimmie (1996b) also report that structural changes in paper sludges subjected to freeze-thaw are different than the changes that occur in compacted clays.

No cracks were observed in the specimens that did not increase in hydraulic conductivity when frozen and thawed [i.e., Sludge A, Fig. 8(a), 9(a)]. After freeze-thaw cycling, the specimens appeared identical to their as-compacted condition.

#### Desiccation

Tests were also conducted to assess how desiccation affects compacted paper mill sludges. One specimen of each sludge was compacted at the Low-K water content and permeated. Afterwards, the specimens were removed from the permeameters and placed on a bench where they could air dry. Weight and volume of the specimens were measured intermittently throughout the drying period (Fig. 10). After one week, the specimens ceased to lose weight after drying. At this point the specimens had shrunk significantly (25–30%, Fig. 10), and shrinkage cracks were evident along their sides and upper and lower surfaces (Fig. 11).

An attempt was made to re-permeate the specimens after ten days of drying. Because of shrinkage, trimming was necessary before the specimens could be permeated in permeameters having standard-size end caps (e.g., 71 mm diameter). During trimming, however, the specimens fell apart along the cracks. Consequently, the postdesiccation hydraulic conductivity of

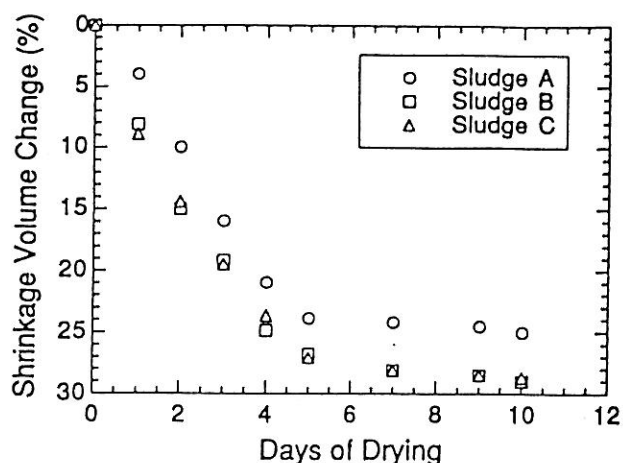


FIG. 10. Volume Change during Drying of Sludges A, B, and C

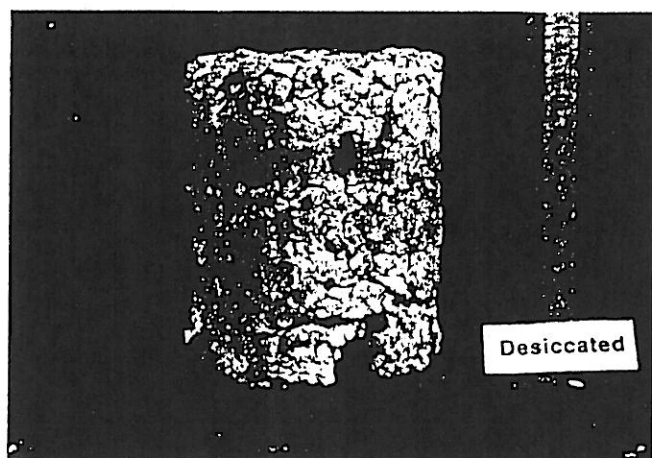


FIG. 11. Desiccated Specimen of Sludge A Prepared at Low-K Water Content

the specimens could not be measured. However, the writers believe that the hydraulic conductivity of these specimens probably increased significantly due to the extensive network of cracks that formed during drying. Similar cracks have been found in compacted clay barrier layers that have desiccated (Benson and Khire 1995; Melchoir et al. 1994; Montgomery and Parsons 1990).

### Long-Term Performance

Gas generated by decomposition of organic matter during permeation was observed in this study and has also been reported by other investigators (NCASI 1989; Genthe 1993; Maltby and Eppstein 1994). To evaluate whether decomposition affected hydraulic conductivity, hydraulic conductivity tests were performed on specimens of each sludge over an extended period of time.

Two specimens of each sludge were compacted using standard Proctor effort; one specimen was compacted at the Low-K water content, whereas the other specimen was compacted at the as-received water content. Rigid-wall compaction-mold permeameters equipped with swell rings, lead surcharge weights, and vent tubes were used for measuring hydraulic conductivity. A hydraulic gradient of six was applied.

Results of the tests are shown in Fig. 12. For each specimen, the hydraulic conductivity remained essentially unchanged or decreased slightly during permeation. Thus, extended permeation appeared to have no adverse impact on hydraulic conductivity for the specimens prepared at either water content for the test period used in this study. This finding is consistent with the field performance of the barrier layers in the NCASI

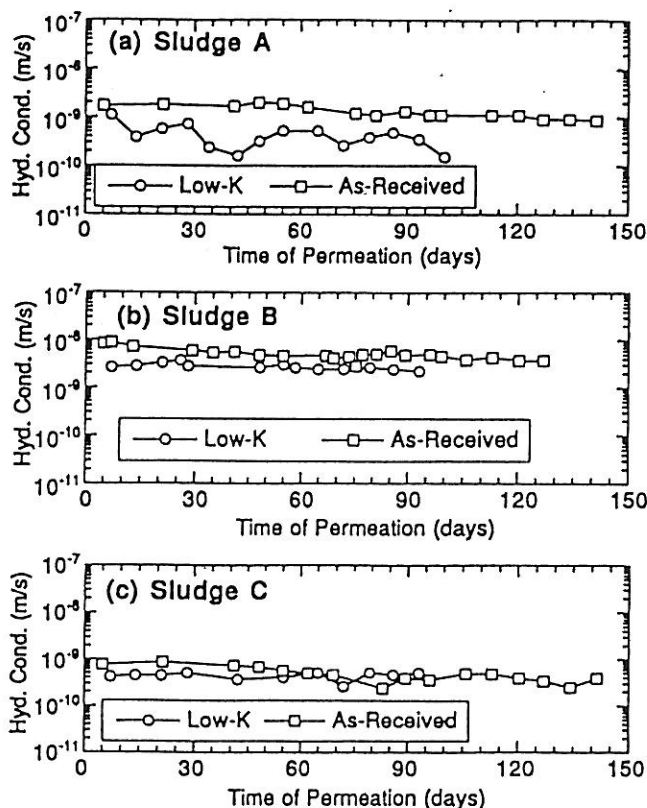


FIG. 12. Hydraulic Conductivity versus Time: (a) Sludge A; (b) Sludge B; and (c) Sludge C

test cells, which showed no increase in hydraulic conductivity eight years after construction. Similar findings have been reported by Zimmie and Moo-Young (1995).

### SUMMARY AND CONCLUSIONS

The paper mill sludges evaluated in this study behave similar to clays when compacted. Compaction curves similar to those for clays were obtained for each sludge, although the optimum water contents were much higher and maximum dry unit weights were much lower than those characteristic of compacted clays. The hydraulic conductivity-molding water content relationships for the sludges were also similar to those for compacted clays. The hydraulic conductivity was four orders of magnitude higher dry of optimum water content compared to wet of optimum water content. These changes in hydraulic conductivity are consistent with the different macrostructures obtained dry and wet of optimum water content. The lowest hydraulic conductivities, which were less than  $1 \times 10^{-9}$  m/s, occurred 50–100% wet of optimum water content.

Hydraulic conductivities measured in the field on barrier layers constructed with Sludges A and B were similar to those measured in the laboratory on undisturbed specimens and on laboratory-compacted specimens prepared at similar molding water contents provided the effective stress in the field and laboratory was essentially the same. Tests conducted at various effective stresses showed that the hydraulic conductivities of paper mill sludges are particularly sensitive to effective stress. Thus, laboratory tests should be conducted at effective stresses expected to exist in a barrier layer after construction. Also, results of field hydraulic conductivity tests should be interpreted with caution if the tests are conducted at effective stresses lower than the stress that will exist after overlying soil layers have been placed. Field tests conducted at effective stresses that are too low will likely yield hydraulic conductiv-

ities higher than the hydraulic conductivity that will exist in the final cover.

Environmental distress caused by desiccation and freeze-thaw affected the structure and hydraulic conductivity of the compacted sludges. Desiccation caused the compacted sludges to shrink and crack, as is typically observed in compacted clays. Although hydraulic conductivity testing of the desiccated sludges was not possible, the extensive crack network that formed in the sludge probably would have resulted in increased hydraulic conductivity. Cracking of Sludges B and C also occurred when specimens were frozen and thawed. Consequently, the hydraulic conductivity increased one to two orders of magnitude after freeze-thaw. In contrast, Sludge A was not affected by freeze-thaw cycling if it was permeated initially and between freeze-thaw cycles. However, when Sludge A was frozen and thawed without intermittent permeation, its hydraulic conductivity increased nearly two orders of magnitude. These findings suggest that some sludges may be resistant to frost damage under certain hydrologic conditions. Nevertheless, the findings of this study also indicate that it is prudent to protect barrier layers constructed with sludge from desiccating and freezing.

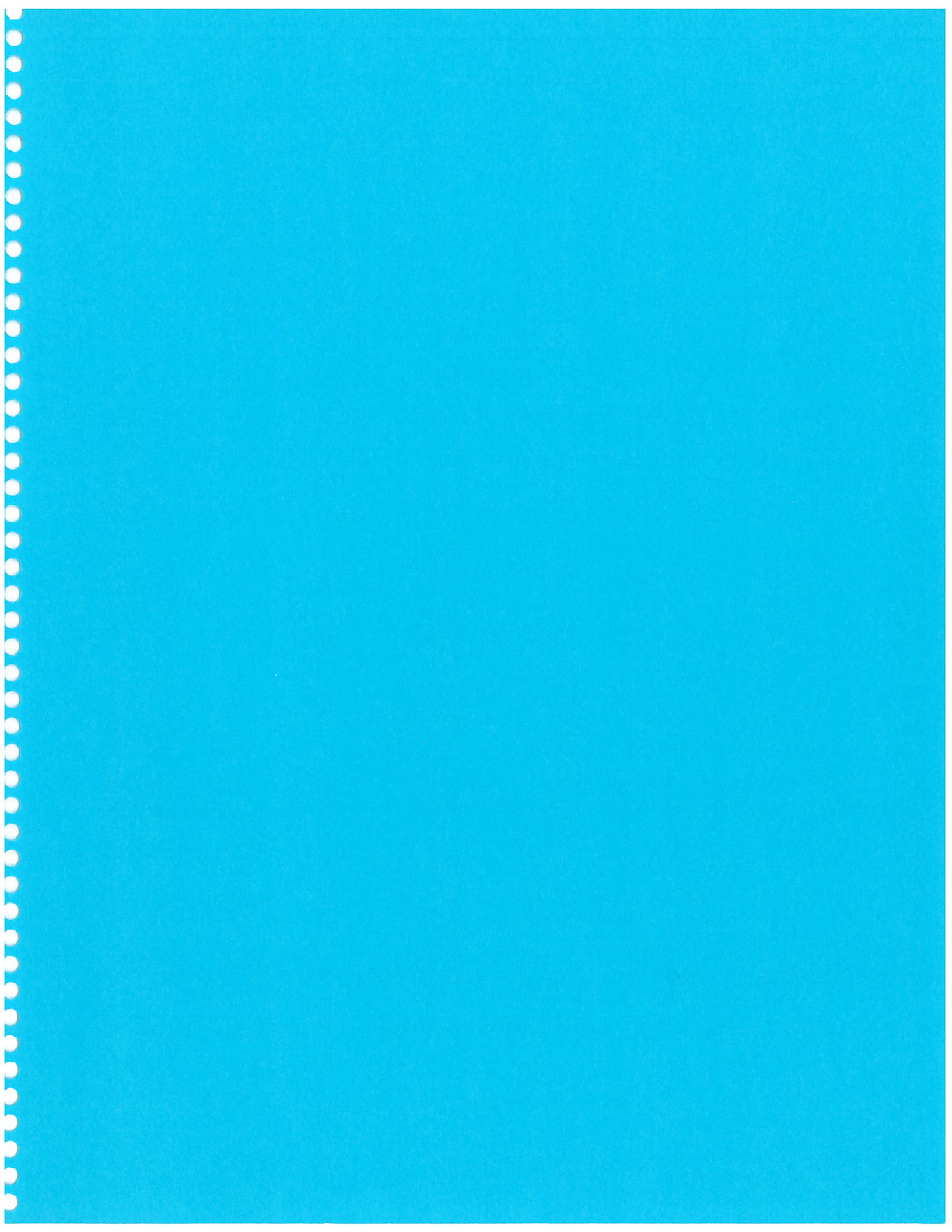
Finally, long-term hydraulic conductivity tests conducted in the laboratory showed that the hydraulic conductivity of paper mill sludge remains the same or decreases slowly during long-term permeation. This finding is consistent with the performance of the barrier layers in the field test cells, which experienced no increase in hydraulic conductivity during their eight-year life. Thus, barrier layers constructed with paper mill sludges are likely to maintain their low hydraulic conductivity, as long as protection is provided against deleterious conditions that result in distress cracking.

## ACKNOWLEDGMENTS

Financial support for this study was provided by the National Council of the Pulp and Paper Industry for Air and Stream Improvement (NCASI) and by the United States Environmental Protection Agency (EPA) under cooperative agreement CR 821024-01-0. Robert Landreth was the Project Officer for EPA. This paper has not been reviewed by EPA and no endorsement should be implied.

## APPENDIX. REFERENCES

- Benson, C., and Boutwell, G. (1992). "Compaction control and scale-dependent hydraulic conductivity of clay liners." *Proc., 15th Annu. Madison Waste Conf.*, Dept. of Engrg. Prof. Devel., Univ. of Wis.-Madison, 62-83.
- Benson, C., and Daniel, D. (1990). "Influence of clods on the hydraulic conductivity of compacted clay." *J. Geotech. Engrg.*, ASCE, 116(8), 1231-1248.
- Benson, C., and Khire, M. (1995). "Earthen covers for semi-arid and arid climates." *Landfill closures*, J. Dunn and U. Singh, eds., ASCE, New York, N.Y., GSP No. 53, 201-217.
- Benson, C., and Wang, X. (1996). "Field hydraulic conductivity assessment of the NCASI final cover test plots." *Envir. Geotechnics Rep. No. 96-9*, Dept. of Civ. and Envir. Engrg., Univ. of Wis.-Madison.
- Benson, C., Hardianto, F., and Motan, E. (1994). "Representative specimen size for hydraulic conductivity assessment of compacted soil liners." *Hydraulic conductivity and waste containment transport in soils*, ASTM STP 1142, Philadelphia, Pa., 3-29.
- Benson, C., Chamberlain, E., Erickson, A., and Wang, X. (1995). "Assessing frost damage in compacted clay liners." *ASTM Geotech. Testing J.*, 18(3), 324-333.
- Daniel, D. (1994). "State-of-the-art: laboratory hydraulic conductivity tests for saturated soils." *Hydraulic conductivity and waste containment transport in soils*, ASTM STP 1142, Philadelphia, Pa., 30-78.
- Erickson, A., Chamberlain, E., and Benson, C. (1994). "Effects of frost action on covers and liners in cold environments." *Proc., 17th Int. Madison Waste Conf.*, Dept. of Engrg., Prof. Devel., Univ. of Wis.-Madison, 198-220.
- Floess, C., Smith, R., and Hitchcock, R. (1995). "Capping with fiber clay." *Civ. Engrg.*, ASCE, 65(8), 62-63.
- Genthe, D. (1993). "Shear strength of two pulp and paper mill sludges with low solids content," MS thesis, University of Wisconsin-Madison, Madison, Wis.
- Kraus, J. (1994). "Effect of freeze-thaw on the hydraulic conductivity of barrier materials: laboratory and field evaluation," MS thesis, Geological Engrg. Program, University of Wisconsin-Madison, Madison, Wis.
- Kraus, J., Benson, C., Erickson, A., and Chamberlain, E. (1997). "Freeze-thaw cycling and the hydraulic conductivity of bentonitic barriers." *J. Geotech. Engrg.*, ASCE, 123(3), 229-238.
- Maltby, V., and Eppstein, L. (1994). "A field-scale study of the use of paper industry sludges as hydraulic barriers in landfill cover systems." *Hydraulic conductivity and waste contaminant transport in soils*, ASTM STP 1142, Philadelphia, Pa., 546-558.
- Melchoir, S., Berger, K., Vielhaber, B., and Miehlisch, G. (1994). "Multi-layered landfill covers: field data on the water balance and liner performance." *In-situ remediation: scientific basis for current and future technologies: 33rd Hanford Symp. on Health and the Environment*, G. Gee and N. Wing, eds., 411-425.
- Mitchell, J., Hooper, D., and Campanella, R. (1965). "Permeability of compacted clay." *J. Soil Mech. and Found. Div.*, ASCE, 91(4), 41-65.
- Montgomery, R., and Parsons, L. (1990). "The omega hills cover test plot study: fourth year data summary." *Proc., 22nd Mid-Atlantic Industrial Waste Conf.*, Drexel University.
- Moo-Young, H. (1992). "Evaluation of the geotechnical properties of paper mill sludge for use in landfill covers," MS thesis, Dept. of Civ. Engrg., Rensselaer Polytechnic Institute, Troy, N.Y.
- Moo-Young, H., and Zimmie, T. (1996a). "Geotechnical properties of paper mill sludges for use in landfill covers." *J. Geotech. Engrg.*, ASCE, 122(9), 768-776.
- Moo-Young, H., and Zimmie, T. (1996b). "Effects of freezing and thawing on the hydraulic conductivity of paper mill sludges used as landfill covers." *Can. Geotech. J.*, Ottawa, Canada, 33(5), 783-792.
- National Council of the Pulp and Paper Industry (NCASI). (1989). "Experience with and laboratory studies of the use of pulp and paper mill solid wastes in landfill cover systems." *Tech. Bull. No. 559*, NCASI, New York, N.Y.
- National Council of the Pulp and Paper Industry (NCASI). (1992). "Chemical composition of pulp and paper industry landfill leachates." *Tech. Bull. No. 643*, NCASI, New York, N.Y.
- Othman, M., and Benson, C. (1993). "Effect of freeze-thaw on the hydraulic conductivity and morphology of compacted clay." *Can. Geotech. J.*, Ottawa, Canada, 30(2), 236-246.
- Othman, M., Benson, C., Chamberlain, E., and Zimmie, T. (1994). "Laboratory testing to evaluate changes in hydraulic conductivity caused by freeze-thaw: state-of-the-art." *Hydraulic conductivity and waste containment transport in soils*, ASTM STP 1142, Philadelphia, Pa., 227-254.
- Pepin, R. (1984). "The use of paper mill sludge as a landfill cap." *Proc., 1983 National Council of the Pulp and Paper Industry Northeast Regional Meeting*, NCASI, New York, N.Y.
- Shan, H.-Y., and Daniel, D. (1991). "Results of laboratory tests on a geotextile/bentonite liner material." *Proc., Geosynthetics '91*, Industrial Fabrics Association International, St. Paul, Minn., 517-536.
- Stoffel, C., and Ham, R. (1979). "Testing of high ash content paper mill sludge for use in sanitary landfill construction." *Rep. Prepared for City of Eau Claire, Wis.*, Ayers and Assoc., Inc.
- TAPPI. (1992). "Fiber length of pulp by classification." *TAPPI Test Methods*, TAPPI Press, New York, N.Y.
- Trast, J., and Benson, C. (1995). "Estimating field hydraulic conductivity at various effective stresses." *J. Geotech. Engrg.*, ASCE, 121(10), 736-740.
- Trautwein, S., and Boutwell, G. (1994). "In-situ hydraulic conductivity tests for compacted soil liners and caps." *Hydraulic conductivity and waste containment transport in soils*, ASTM STP 1142, Philadelphia, Pa., 184-226.
- Zimmie, T., and Moo-Young, H. (1995). "Hydraulic conductivity of paper sludges used for landfill covers." *Geoenvironment 2000*, GSP No. 46, Y. Acar and D. Daniel, eds., ASCE, New York, N.Y., 932-946.
- Zimmie, T., Moo-Young, H., and La Plante, K. (1993). "The use of waste paper sludge for landfill cover material." *Green '93: Waste Disposal by Landfill; An Int. Symp. on Geotechnics Related to the Environment*, Bolton Institute, Bolton, U.K., Vol. 2, 11-19.





## ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

Governor Jane Dee Hull

Russell F. Rhoades, Director

September 17, 1997

REF: PRU97-451

Ben Fisk  
City of Flagstaff  
211 West Aspen Avenue  
Flagstaff, Arizona 86001

### RE: Cinder Lake Municipal Solid Waste Landfill - Alternate Daily Cover Pilot Project

Dear Mr. Fisk:

The Arizona Department of Environmental Quality (ADEQ) received an August 13, 1997, letter and report from the City of Flagstaff's (City) consultant, Woodward-Clyde, requesting approval to conduct a pilot project for the use of paper pulp waste as an alternate daily cover (ADC) at the Cinder Lake Landfill. Pursuant to Arizona Revised Statute (ARS) § 49-723, ADEQ may support demonstration projects directed toward improving solid waste management. The purpose of using paper pulp waste as an ADC at the Cinder Lake Landfill is to conserve air space and reduce landfill operational costs.

Since paper pulp waste has not been used as an ADC at other municipal solid waste facilities in Arizona and may improve the City's solid waste management, ADEQ may grant approval to Cinder Lake Municipal Solid Waste Landfill to perform a one-year pilot project of paper pulp waste as an ADC subject to the following conditions:

1. The analytical reports contained in Appendix B of Woodward-Clyde's August 13, 1997, report do not show tests results for selenium, silver, chlordane, Endrin, heptachlor, methoxychlor, toxaphene, 2,4-D, and 2,4,5-TP (Silvex). The City may not initiate the pilot project until ADEQ receives and approves the results of a complete Toxicity Characteristic Leaching Procedure (TCLP).
2. In accordance with ARS § 49-723.C, the pilot project will not extend beyond a one year period from the date paper pulp waste is first used as an ADC. Within 10 days of the initiation of the pilot project, the City will notify ADEQ in writing of the start date.
3. The paper pulp waste shall be tested, at least once during the pilot project, using either ASTM E1354 (Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products, Using an Oxygen Consumption Calorimeter) or an equivalent test to determine if it meets the flammability requirement of daily cover. The test will be conducted on paper pulp waste which has a maximum moisture content of 65%.

- ✓ 4. Daily data will be collected and reported on the data collection worksheet in Appendix A of Woodward-Clyde's August 13, 1997, report.
5. The paper pulp waste will be analyzed on a semiannual basis during the pilot project using the TCLP and the Paint Filter Liquids Test. The tests will be made on paper pulp waste at the time it is applied to the working surface of the landfill.
- ✓ 6. The City will not maintain a stockpile of paper pulp waste greater than 150 cubic yards. Use of existing landfill equipment, scraper, dozer (Caterpillar D8N), and compactor (Caterpillar 826C), will be used to apply the paper pulp waste to the working face of the landfill. Once applied, at least two passes with either the dozer or compactor will be made to a thickness of at least 12 inches.
- ✓ 7. Should the City or ADEQ notice that the paper pulp waste is not providing adequate protection or becomes a threat to human health or the environment, the City will initiate any changes in the daily cover operation necessary to comply with the requirements of daily cover. Further, the City will stockpile a sufficient quantity of soil to be used as daily cover in the event that the paper pulp waste fails in any of its functions. The stockpiled soil and the 3,000 gallon water truck will be used for fire suppression.
- ✓ 8. The minimum soil moisture content of the paper pulp waste used as an ADC is 65%. If the material becomes a dust nuisance, sufficient water will be applied immediately to eliminate the nuisance.
- ✓ 9. Paper pulp waste will be applied following the ramping-up schedule as proposed in Woodward-Clyde's August 13, 1997, report. If for any reason it becomes apparent to the City or ADEQ that the paper pulp waste has been exposed for too long of a period of time, the ramping-up schedule will be discontinued. The paper pulp waste will not be exposed for more than 30 days.
- ✓ 10. Paper pulp waste will not be used as ADC during raining conditions.
11. Pursuant to 40 CFR 258.21, daily cover is defined as six inches of earthen material applied over the exposed solid waste at the end of each working day to control disease vectors, fires, odors, blowing litter, and scavenging. A daily cover is also expected to control dust, improve general site aesthetics, and act as a moisture barrier from infiltrating the waste. It must be demonstrated that the ADC meets the above functional requirements of daily cover without presenting a threat to human health or the environment. ADC should be nonflammable and should minimize potential fire hazards by limiting the movement of atmospheric oxygen into the waste and impeding the spread of fire in the landfill. Data collection during the pilot project is required to demonstrate that the ADC of paper pulp

Ben Fisk  
September 17, 1997  
Page 3 of 3

waste will function as a barrier to the 1) emergence or attraction of vectors, 2) progression of landfill fires within the landfill, 3) escape of odor, 4) excess infiltration, 5) blowing of litter, and 6) scavenging.

A summary report, addressing the aforementioned functions of daily cover, will be submitted to ADEQ within one month of the end of the pilot project or from the date the pilot project is stopped for any reason. Additionally, the city shall maintain results of the pilot project in the facility's operating record and furnish this information to ADEQ upon request.

Again, prior to issuing approval of this pilot project, ADEQ requests that the City of Flagstaff submit complete results of a complete Toxicity Characteristic Leaching Procedure.

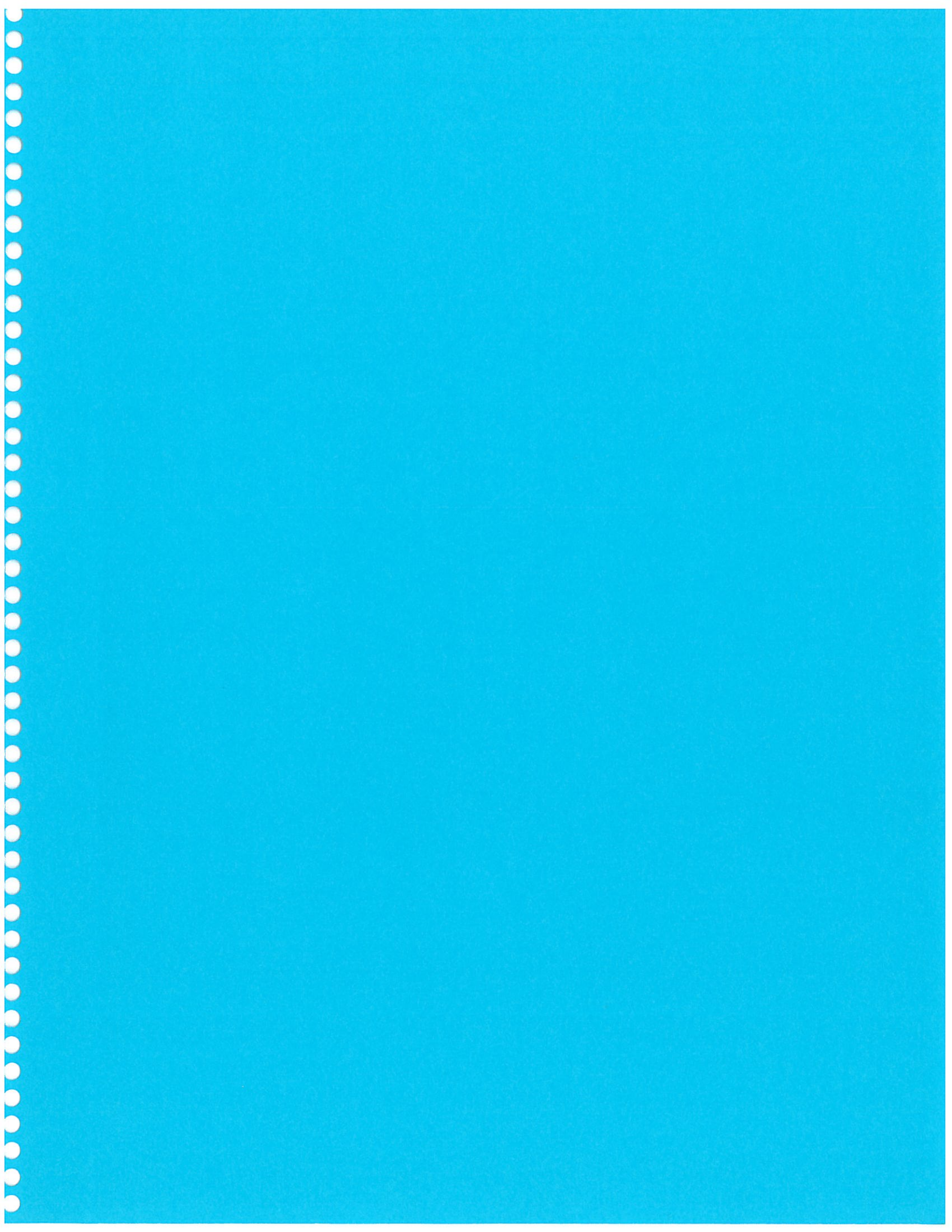
If you have any questions, or would like to schedule a meeting regarding this letter, please contact me at (602) 207-4581, or toll free (in Arizona) at (800) 234-5677 Ext. 4581.

Sincerely,



Gregory H. Brown, P.E.  
Solid Waste Plan Review Unit

cc: Norm Gumenik, Solid Waste Section  
Byron James, Plan Review Unit  
Nicole Heffington, Plan Review Unit  
Joe Giudice, Inspections and Compliance Unit  
Facility File





# City of Flagstaff

October 28, 1997

Mr. Gregory Brown, P.E.  
Solid Waste Plan Review Unit  
Arizona Department of Environmental Quality  
3033 North Central Avenue  
Phoenix, AZ 85012

Dear Mr. Brown:

The City of Flagstaff (City) received a September 17, 1997, letter from the Arizona Department of Environmental Quality (ADEQ) which outlined the conditions under which ADEQ would grant approval of the City's proposed pilot project to use paper pulp waste as an alternative daily cover (ADC) at the Cinder Lake Landfill. This letter will address ADEQ's conditions for the pilot project and will serve as a 10 day notice of the initiation of the pilot project, which the City anticipates starting on November 17, 1997.

The conditions listed in ADEQ's September 17, 1997, letter are addressed here in the order in which they were listed in ADEQ's letter.

1. ADEQ stated that the City could not initiate the pilot project until ADEQ received and approved the results of a complete Toxicity Characteristic Leaching Procedure (TCLP). ADEQ cited nine parameters that were lacking TCLP results in the information previously submitted to ADEQ by the City and their consultant, Woodward-Clyde. Wisconsin Tissue, the producer of the paper pulp waste, has supplied the City with the results of a complete TCLP analysis conducted on a sample they collected on September 29, 1997. The analysis was conducted by VOC Analytical Laboratories, Inc. of Glendale, California. This laboratory is licensed by the Arizona Department of Health Services, license #AZ0512.

The complete results of this analysis are attached to this letter. The results for the nine parameters that were lacking in the information previously submitted are listed below in Table 1 along with the Regulatory Levels from 40 CFR 261.24, Identification and Listing of Hazardous Waste, Toxicity Characteristic. Review of the TCLP results indicates that all parameters analyzed are below the regulatory limits listed in 40 CFR 261.24.



**Table 1**  
Paper Pulp Waste TCLP Results  
Compared to 40 CFR 261.24 Regulatory Limits

Parameter	Result from 9/29/97 Sampling, mg/L	Regulatory Limit, mg/L
Selenium	0.11	1.0
Silver	<0.01	5.0
Chlordane	<0.0006	0.03
Endrin	<0.00002	0.02
Heptachlor	<0.00002	0.008
methoxychlor	<0.00003	10.0
toxaphene	<0.002	0.5
2,4,-D	<0.02	10.0
2,4,5-TP (Silvex)	<0.004	1.0

mg/L = milligrams per Liter

- ADEQ requires that the pilot project not extend beyond one year from the date paper pulp waste is first used as ADC. ADEQ also requires notification, in writing, within ten (10) days of initiation of the pilot project. **This letter serves as notification that the City intends to begin using paper pulp as ADC at Cinder Lake Landfill on November 17, 1997, unless notified by ADEQ to proceed otherwise.**
- ADEQ required that paper pulp waste used as ADC be tested by ASTM Method E1354 (Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products, Using an Oxygen Consumption Calorimeter), or an equivalent test, at least once during the pilot project. Sarah Kelly, Environmental Scientist for the City, called several laboratories around the country specializing in paper process analyses. None of the three laboratories contacted were equipped to perform ASTM E1354 or an equivalent analysis. Ms. Kelly contacted Mr. Greg Brown of ADEQ. Mr. Brown stated that ADEQ required ASTM E1354 in order to show that the paper pulp waste is not flammable or ignitable. Mr. Brown suggested we contact Mr. Mark Chadwallader, Chairman of the ASTM Committee that is putting together a draft guideline on ADCs for landfills.

Ms. Kelly contacted Mr. Chadwallader on October 2, 1997. Mr. Chadwallader stated that the ASTM Committee is not endorsing any particular fire control test method for proposed alternative daily covers because laboratories are unable to adequately simulate actual landfill conditions. Mr. Chadwallader stated that other landfills just keep close observations on their alternative daily covers that are in use in the field. He stated that landfills using paper pulp waste as alternative daily covers in the northeast U.S. rely on other methods to suppress landfill fires such as carefully excluding loads of flammable materials, and keeping piles of soil and adequate water onsite for fire control. Mr. Chadwallader stated that he would not say "yay" or "nay" to a paper pulp waste as alternative daily cover, based on the results of any laboratory test.

The City proposes to use fire suppression methods, in concert with close observation of the paper pulp waste used as ADC, in lieu of completing the ASTM E1354 testing. As stated in Woodward-Clyde and the City's August 13, 1997, submittal to ADEQ, a soil stockpile maintained for use as intermediate cover, will be kept available to be used for fire suppression. The 3,200 gallon water truck used for dust control at Cinder Lake Landfill will also be kept ready to be used for fire control.

4. Daily data will be collected and reported on the data collection sheet similar to the draft form in Appendix A of Woodward-Clyde's August 13, 1997, report. The daily data collection sheets will be kept on file, available for inspection at Cinder Lake Landfill, and included in our summary report to ADEQ.
5. ADEQ requires that the paper pulp waste be analyzed on a semiannual basis during the pilot project, using TCLP and Paint Filter Liquids Test. The City will collect these samples from the paper pulp waste at the time it is applied to the working face of the landfill. Results of these analyses will be kept on file, available for inspection at Cinder Lake Landfill, and included in our summary report to ADEQ.
6. The City will not maintain a stock pile of paper pulp waste greater than 150 cubic yards. Once paper pulp waste is applied to the working surface, at least two passes will be made with the dozer or compactor to compact the paper pulp waste to a thickness of 12 inches or alternate thickness, if approved.
7. If, at any time during the pilot project, the City or ADEQ notices the paper pulp waste is not providing adequate protection, the City will initiate any changes in the daily cover operation necessary to comply with the requirements of daily cover. The City will maintain a soil stockpile to be used as daily cover in the event that the paper pulp waste fails in any of its functions. This soil stockpile will also be used for fire suppression.
8. If the paper pulp waste becomes a dust nuisance, sufficient water will be applied immediately to eliminate the nuisance.
9. The paper pulp waste will be applied following the ramping-up schedule, as proposed in Woodward-Clyde's August 13, 1997, report. The paper pulp waste will not be exposed for more than 30 days.
10. Paper pulp will not be used as ADC when it is raining.
11. During the pilot project, the City will take all reasonable measures to ensure the paper pulp waste fulfills all of the requirements for ADC as listed in 40 CFR 258.21.

The City also proposes assessing the effectiveness of varying the paper pulp waste thickness for ADC. If after 3 months, the 12-inch thickness of paper pulp waste appears to meet all of the requirements for an ADC, the City proposes to reduce the paper pulp waste ADC thickness to 8

Gregory Brown, P.E.

October 28, 1997

Page 4

to 10 inches. After reducing the thickness, the City will go back to the first step of the ramping-up schedule to re-evaluate the effectiveness of the paper pulp waste at the 8 to 10 inch thickness. If at any time the reduced thickness does not fulfill all of the requirements for ADC, the City will return to the 12 inch thickness.

The City will provide ADEQ with a summary report addressing the aforementioned functions of daily cover within one month of the end of the pilot project or from the date the pilot project is stopped, for any reason.

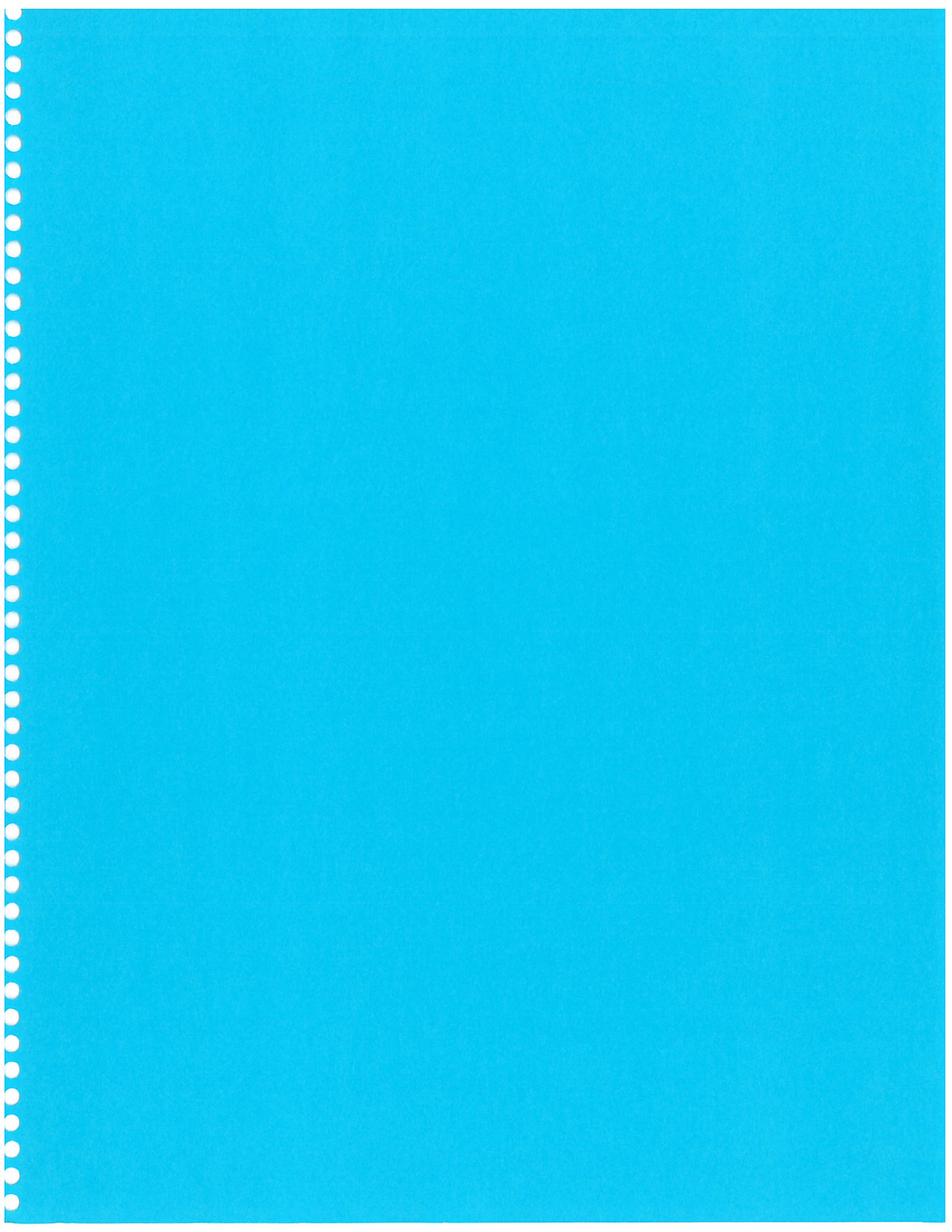
Please contact me at (520) 779-7685, ext. 276, with any comments or concerns you have regarding the start of this pilot project.

Sincerely,



Ben Fisk  
Solid Waste Superintendent

skelly\cindlake\ADCADEQ1





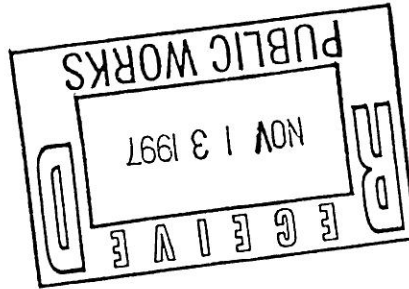
## ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

Governor Jane Dee Hull

Russell F. Rhoades, Director

November 6, 1997  
REF: PRU97-553

Ben Fisk  
City of Flagstaff  
211 West Aspen Avenue  
Flagstaff, Arizona 86001



**RE: Cinder Lake Municipal Solid Waste Landfill - Alternate Daily Cover Pilot Project**

Dear Mr. Fisk:

The Arizona Department of Environmental Quality's (ADEQ) Solid Waste Plan Review Unit (PRU) received and reviewed your October 28, 1997, letter, which responds to ADEQ's September 17, 1997, letter (REF:PRU97-451) outlining ADEQ's conditions for using paper pulp waste as an alternate daily cover (ADC) during a one (1) year pilot project at the Cinder Lake Landfill. Your letter also serves as the 10 day notice to ADEQ of the initiation of the pilot project. Pursuant to Arizona Revised Statute (ARS) § 49-723 et seq., ADEQ approves the pilot project using paper pulp waste as an ADC at the Cinder Lake Landfill starting on November 17, 1997 for one (1) year.

In addition to the conditions stated in ADEQ's September 17, 1997, letter, the City of Flagstaff proposes to vary the thickness of the ADC from twelve (12) inches to between eight (8) and ten (10) inches after three (3) months if the twelve (12) inch thickness is meeting all the requirements of an ADC. ADEQ understands that, if the alternative thickness does not fulfill all of the requirements for an ADC, the City of Flagstaff will return to the 12 inch thickness. This demonstration of an alternative thickness is approved.

The pilot project shall be conducted in accordance with the conditions as set forth in ADEQ's letter addressed to you dated September 17, 1997, (REF:PRU97-451) and your letter dated October 28, 1997. Should the City of Flagstaff or ADEQ notice that the paper pulp waste is not providing adequate protection or becomes a threat to human health or the environment, the City of Flagstaff shall initiate any changes in the daily cover operation necessary to comply with the requirements of daily cover.

Ben Fisk  
November 6, 1997  
Page 2 of 2

If you have any questions, or would like to schedule a meeting regarding this letter, please contact me at (602) 207-4581, or toll free (in Arizona) at (800) 234-5677 Ext. 4581. Your response letters may be addressed to me.

Sincerely,



Gregory H. Brown, P.E.  
Solid Waste Plan Review Unit

cc: Norm Gumenik, Solid Waste Section  
Byron James, Plan Review Unit  
Nicole Heffington, Plan Review Unit  
Steve Tighe, Plan Review Unit  
Joe Giudice, Inspections and Compliance Unit  
Facility File

## **APPENDIX B**

# CINDER LAKE LANDFILL PAPER PULP WASTE ADC DATA SHEET

NAME: Mike Gyller

DATE/TIME: 12/4/97  
5:30 P.M.

PREDOMINANT WEATHER (check all that apply)

☐ cloudy   ☐ rain   ☒ sunny   ☐ windy   ☐ snow

Temperature	
<u>40</u> high	<u>6</u> low

## CHECK THE APPROPRIATE BOX

1. Pilot Project has attracted

YES  
(Detail below)

NO

Flies

☐
☒

Birds

☐
☒

Rodents

☐
☒

Mosquitoes

☐
☒

Other animals

☐
☒

2. Evidence of scavenging observed

☐
☒

3. Increased odors detected from pilot project

☐
☒

4. Increased dust observed from pilot project

☐
☒

5. Increased blowing litter observed from pilot project

☐
☒

6. Potential fire hazard conditions observed

☐
☒

7. Operation problems related to the use of ADC

☐
☒

8. Paper pulp received appeared normal

☒
☐

9. Trash exposed

☐
☒

10. Number of paper pulp waste trucks deliveries received

8

Number of tons

126.83

11. Number of cu. yds paper pulp waste used as ADC

220

12. Maximum number of days paper pulp waste ADC exposed

1

13. Depth of cover, checked in 3 places (min.) 14 12 16 15 inches

14. Quantity of pulp stockpiled at end of day

0 cu. yds.

15. Quantity of soil stockpiled at end of day

120 cu. yds.

Other issues, problems and observations

**CINDER LAKE LANDFILL  
PAPER PULP WASTE ADC DATA SHEET**

NAME: Mike Gullors

DATE/TIME: 3/31/98

PREDOMINANT WEATHER (check all that apply)

☐ cloudy    ☐ rain    ☒ sunny    ☐ windy    ☐ snow

Temperature	
<u>61</u> high	<u>12</u> low

CHECK THE APPROPRIATE BOX

- |   | YES<br>(Detail below)                          | NO                                  |
|---|--|-------------------------------------|
| 1. Pilot Project has attracted                            |  |                                     |
| Flies   | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| Birds   | <input type="checkbox"/>                       | <input type="checkbox"/>            |
| Rodents   | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| Mosquitoes  | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| Other animals   | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 2. Evidence of scavenging observed                        | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 3. Increased odors detected from pilot project            | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 4. Increased dust observed from pilot project             | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 5. Increased blowing litter observed from pilot project   | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 6. Potential fire hazard conditions observed              | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 7. Operation problems related to the use of ADC           | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 8. Paper pulp received appeared normal                    | <input checked="" type="checkbox"/>            | <input type="checkbox"/>            |
| 9. Trash exposed  | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 10. Number of paper pulp waste trucks deliveries received | <u>10</u>                                      |                                     |
| Number of tons  | <u>216.68</u>                                  |                                     |
| 11. Number of cu. yds paper pulp waste used as ADC        | <u>80</u>                                      |                                     |
| 12. Maximum number of days paper pulp waste ADC exposed   | <u>1</u>                                       |                                     |
| 13. Depth of cover, checked in 3 places (min.)            | <u>12</u> <u>14</u> <u>12</u> <u>14</u> inches |                                     |
| 14. Quantity of pulp stockpiled at end of day             | <u>320</u> cu. yds.                            |                                     |
| 15. Quantity of soil stockpiled at end of day             | <u>200</u> cu. yds.                            |                                     |
| Other issues, problems and observations                   | <u></u>  |                                     |

**CINDER LAKE LANDFILL  
PAPER PULP WASTE ADC DATA SHEET**

NAME: Carlton Johns Jr

DATE/TIME: 6/25/98

PREDOMINANT WEATHER (check all that apply)

☐ cloudy   ☐ rain   ☒ sunny   ☒ windy   ☐ snow  
28 mph

Temperature	
<u>77</u> high	<u>40</u> low

( 28 mph )

CHECK THE APPROPRIATE BOX

- |   | YES<br>(Detail below)                          | NO                                  |
|---|--|-------------------------------------|
| 1. Pilot Project has attracted                            |  |                                     |
| Flies   | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| Birds   | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| Rodents   | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| Mosquitoes  | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| Other animals   | <input type="checkbox"/>                       | <input type="checkbox"/>            |
| 2. Evidence of scavenging observed                        | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 3. Increased odors detected from pilot project            | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 4. Increased dust observed from pilot project             | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 5. Increased blowing litter observed from pilot project   | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 6. Potential fire hazard conditions observed              | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 7. Operation problems related to the use of ADC           | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 8. Paper pulp received appeared normal                    | <input checked="" type="checkbox"/>            | <input type="checkbox"/>            |
| 9. Trash exposed  | <input type="checkbox"/>                       | <input checked="" type="checkbox"/> |
| 10. Number of paper pulp waste trucks deliveries received | <u>3</u>                                       |                                     |
| Number of tons  | <u>62.93</u>                                   |                                     |
| 11. Number of cu. yds paper pulp waste used as ADC        | <u>160</u>                                     |                                     |
| 12. Maximum number of days paper pulp waste ADC exposed   | <u>15</u>                                      |                                     |
| 13. Depth of cover, checked in 3 places (min.)            | <u>12</u> <u>12</u> <u>12</u> <u>12</u> inches |                                     |
| 14. Quantity of pulp stockpiled at end of day             | <u>40</u> cu. yds.                             |                                     |
| 15. Quantity of soil stockpiled at end of day             | <u>200</u> cu. yds.                            |                                     |
| Other issues, problems and observations                   | <u></u>  |                                     |

**CINDER LAKE LANDFILL  
PAPER PULP WASTE ADC DATA SHEET**

NAME: Elssesser

DATE/TIME: 8-30 5:00pm

PREDOMINANT WEATHER (check all that apply)

☒ cloudy   ☒ rain   ☐ sunny   ☐ windy   ☐ snow

Temperature	
<u>72</u> high	<u>53</u> low

WIND 8 mph

CHECK THE APPROPRIATE BOX

1. Pilot Project has attracted

YES  
(Detail below)

NO

Flies

☐
☒

Birds

☐
☒

Rodents

☐
☒

Mosquitoes

☐
☒

Other animals

☐
☒

2. Evidence of scavenging observed

☐
☒

3. Increased odors detected from pilot project

☐
☒

4. Increased dust observed from pilot project

☐
☒

5. Increased blowing litter observed from pilot project

☐
☒

6. Potential fire hazard conditions observed

☐
☒

7. Operation problems related to the use of ADC

☐
☒

8. Paper pulp received appeared normal

☒
☐

9. Trash exposed

☐
☒

10. Number of paper pulp waste trucks deliveries received

6

Number of tons

6

11. Number of cu. yds paper pulp waste used as ADC

120

12. Maximum number of days paper pulp waste ADC exposed

1

13. Depth of cover, checked in 3 places (min.) 12 12 12 14 inches

14. Quantity of pulp stockpiled at end of day 280 cu. yds.

15. Quantity of soil stockpiled at end of day 200 cu. yds.

Other issues, problems and observations \_\_\_\_\_